Search for Dijet Resonance in pp Collisions at CMS

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About Myself

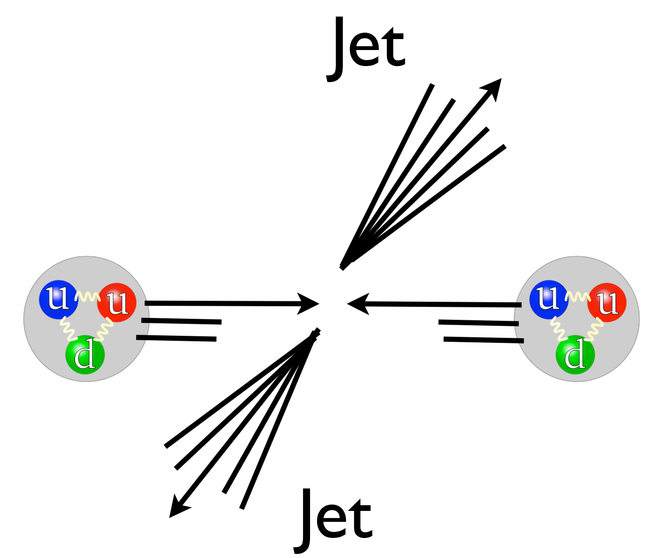
- ✓ I am graduate student at Cukurova University, in Turkey.
- ✓ I have been at LPC for 2 years and my Ph.D. thesis research has been being done at LPC.
    - Search for new physics with jets with Dr. Robert M. Harris
    - HCAL with Dr. Shuichi Kunori
- ✓ I plan to graduate in December.

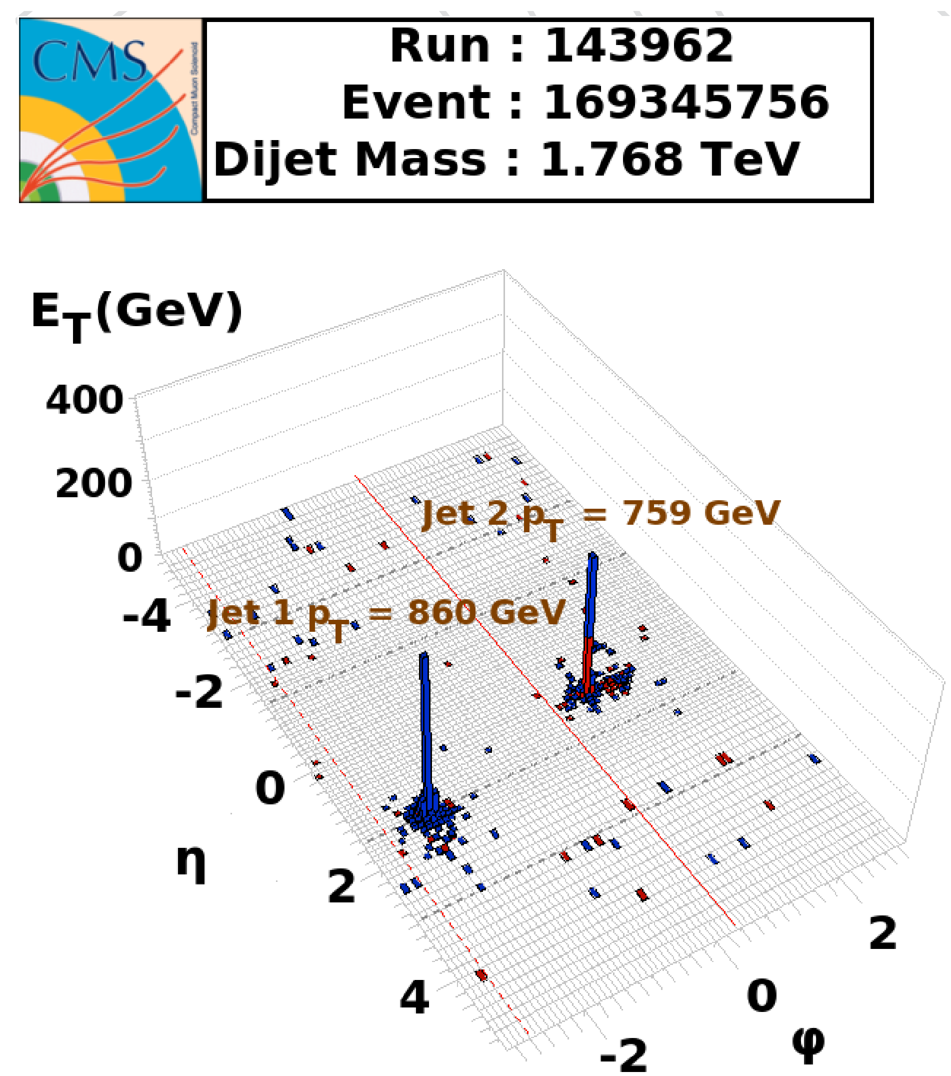
Search for Dijet Resonance

- A MC based analysis was done for 10 TeV collisions and a CMS reviewed paper (*PAS QCD 2009-006*) and an analysis note (*CMS AN-2009/070*) were written
- The results based on **120 nb^{-1}** (*PAS EXO 2010-001*) were approved for ICHEP 2010
- The results based on **836 nb^{-1}** data (*PAS EXO 2010-010*) were approved for HCP 2010
- The results based on **2.88 pb^{-1}** data will be submitted to PRL (hopefully this Friday) and it will cover my Ph.D. thesis.
  - My talk will be based on the latest data.

Dijet in Standard Model

- What is a Dijet?
  - ✓ Dijet results from simple 2→2 scattering of "partons"
  - ✓ Dijets are events which primarily consist of two jets in the final state.
- We search for the new particles in "Dijet Mass" spectrum
  - ✓ If a resonance exist, It can show up as a bump in Dijet Mass spectrum
- Dijet Mass from final state

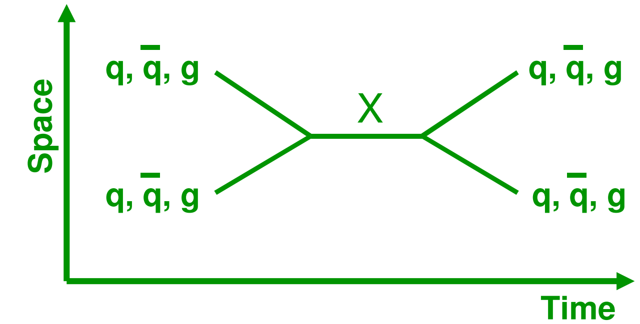


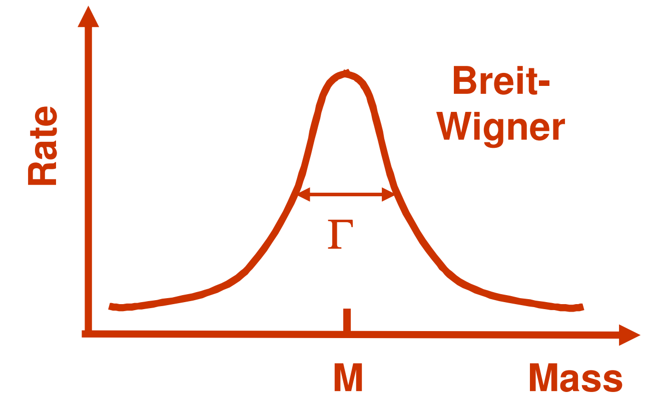


$$m = \sqrt{(E_1 + E_2)^2 - (\vec{p}_1 + \vec{p}_2)^2}$$

Resonance Models

Model Name	X	Color	J^P	$\Gamma/(2M)$	Chan
Excited Quark	q*	Triplet	$1/2^+$	0.02	qg
E_6 Diquark	D	Triplet	0^+	0.004	qq
Axigluon	A	Octet	1^+	0.05	$q\bar{q}$
Coloron	C	Octet	1^-	0.05	$q\bar{q}$
RS Graviton	G	Singlet	2^+	0.01	$q\bar{q}$, gg
Heavy W	W′	Singlet	1^-	0.01	$q\bar{q}$
Heavy Z	Z′	Singlet	1^-	0.01	$q\bar{q}$
String	S	mixed	mixed	0.003 – 0.037	$q\bar{q}$, qq, gg and qg





- The models which are considered in this analysis are listed.
  - ✓ Produced in "s-channel"
  - ✓ Parton-Parton Resonances
    - Observed as dijet resonances.
- Search for model with narrow width Γ.

Experimental Technique

- Measurement of dijet mass spectrum
- Comparison to PYTHIA QCD Monte Carlo prediction
- Fit of the measured dijet mass spectrum with a smooth function and search for resonance signal (bump)
- If no evidence, calculate cross section upper limit and compare with model cross section.

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Data Sample

- Dataset
  - ✓ (135059-135735) - /MinimumBias/Commissioning10-SD_JetMETTau-Jun14thSkim_v1/RECO
  - ✓ (136066-137028) - /JetMETTau/Run2010A-Jun14thReReco_v2/RECO
  - ✓ (137437-139558) - /JetMETTau/Run2010A-PromptReco-v4/RECO
  - ✓ (139779-140159) - /JetMETTau/Run2010A-Jul16thReReco-v1/RECO
  - ✓ (140160-141899) - /JetMETTau/Run2010A-PromptReco-v4/RECO
  - ✓ (141900-142664) - /JetMET/Run2010A-PromptReco-v4/RECO
- /QCDDijet_PtXXtoYY/Spring10-START3X_V26_S09-v1/GEN-SIM-RECO
- Official JSON Files
- Estimated Integrated Luminosity: 2.875 pb-1 (with 11% uncertanity)

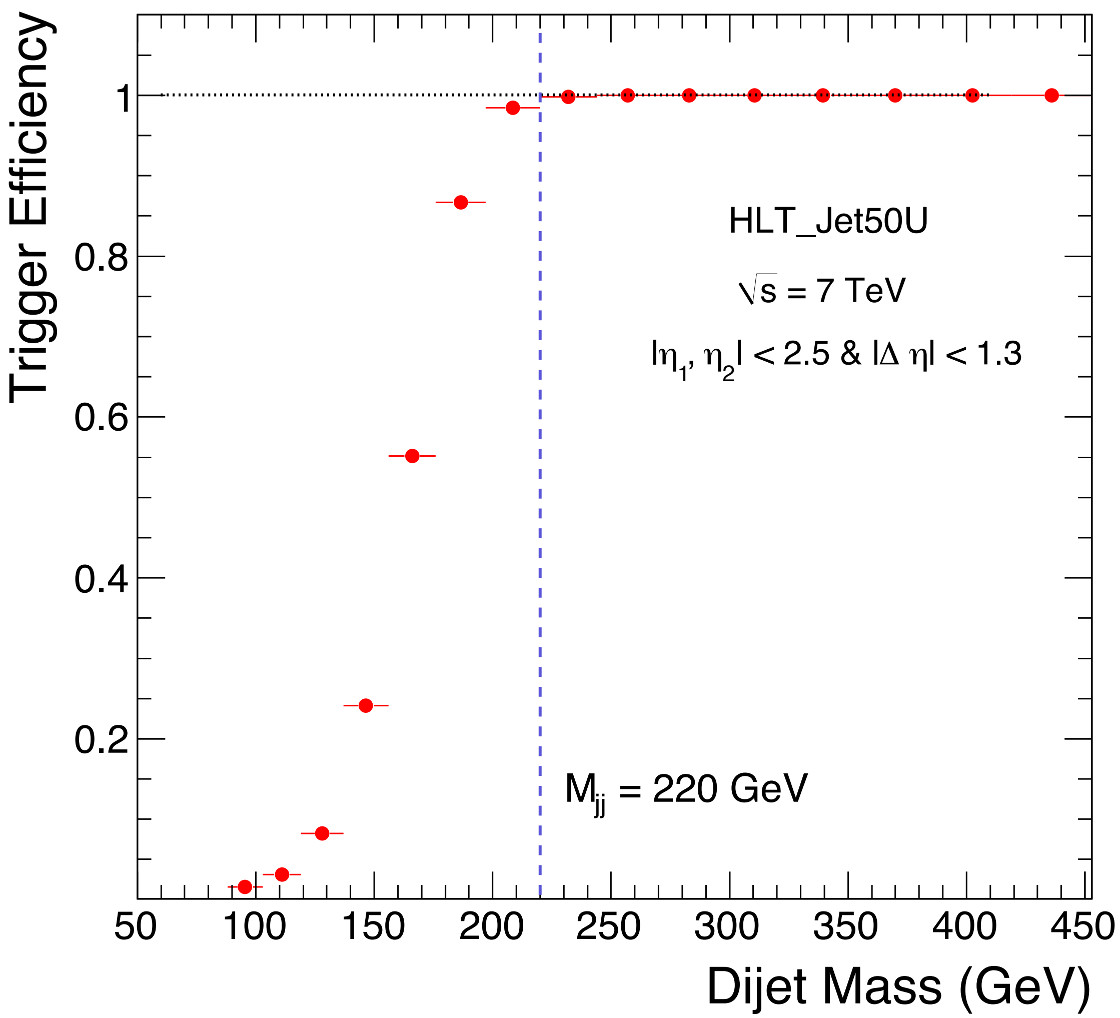
Event Selection

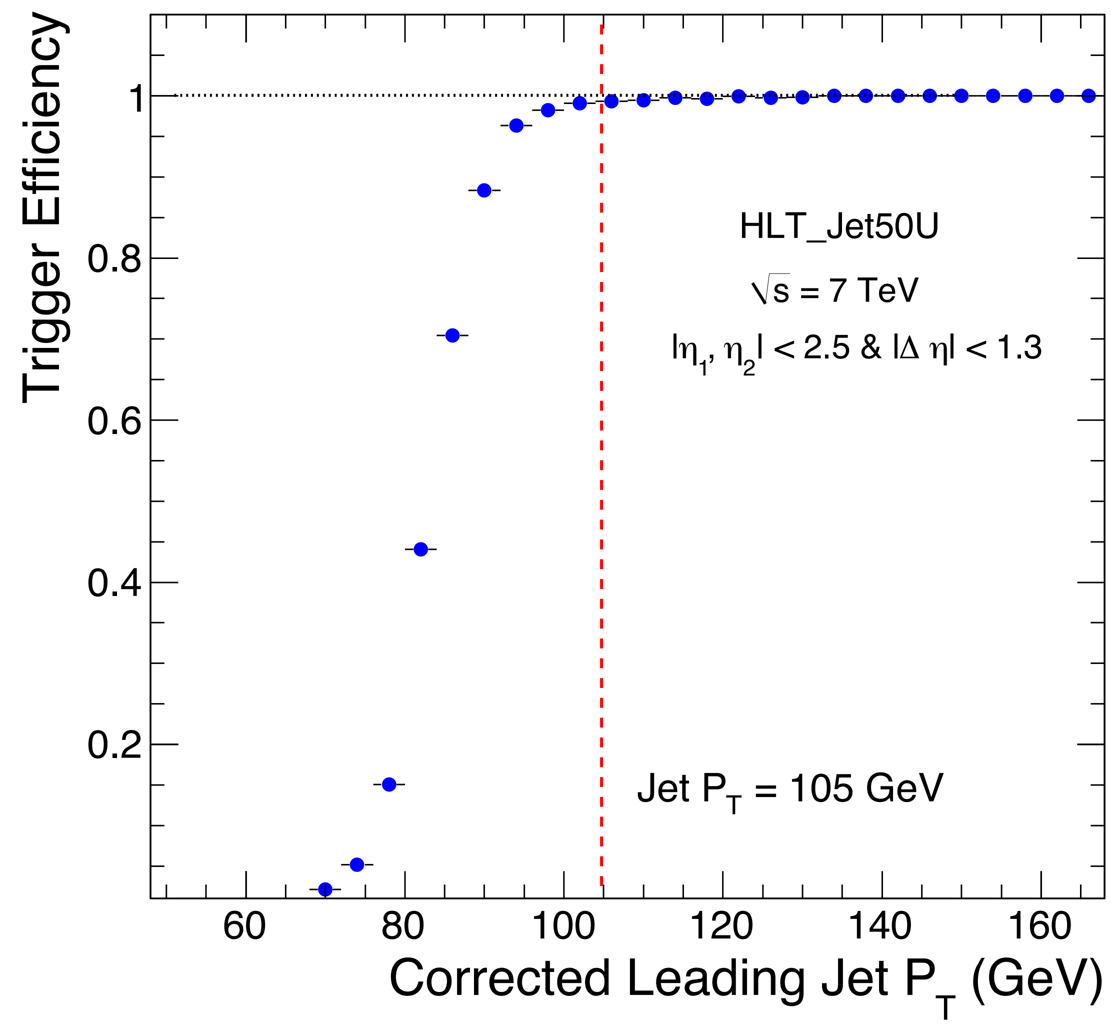
- Trigger
  - ✓ Technical Bit TT0 (for beam crossing)
  - ✓ HLT_Jet50U (un-prescaled)
- Event Selection
  - ✓ Good primary vertex
  - ✓ At least two reconstructed jets
    - AK7caloJets
    - JEC: L2+L3, "Summer10" + Residual Data-Driven
  - ✓ Require both |Jet η|< 2.5 and |Δη|<1.3
    - Suppress QCD process significantly.
  - ✓ Require both leading jets passing the "loose" jet id & Mjj > 220 GeV (corrected)

	Events	Fraction
Events after pre-selection cut	6126910	100%
Events after vertex cut	6125930	99.98%
Events after dijet eta cuts	2088922	34.09%
Events after dijet mass cut	414645	6.78%
Events after jet id cut	414131	6.76%

Trigger Efficiency

- Start analysis of Dijet Mass distribution at 220 GeV.
  - ✓ 220 GeV chosen for full trigger efficiency





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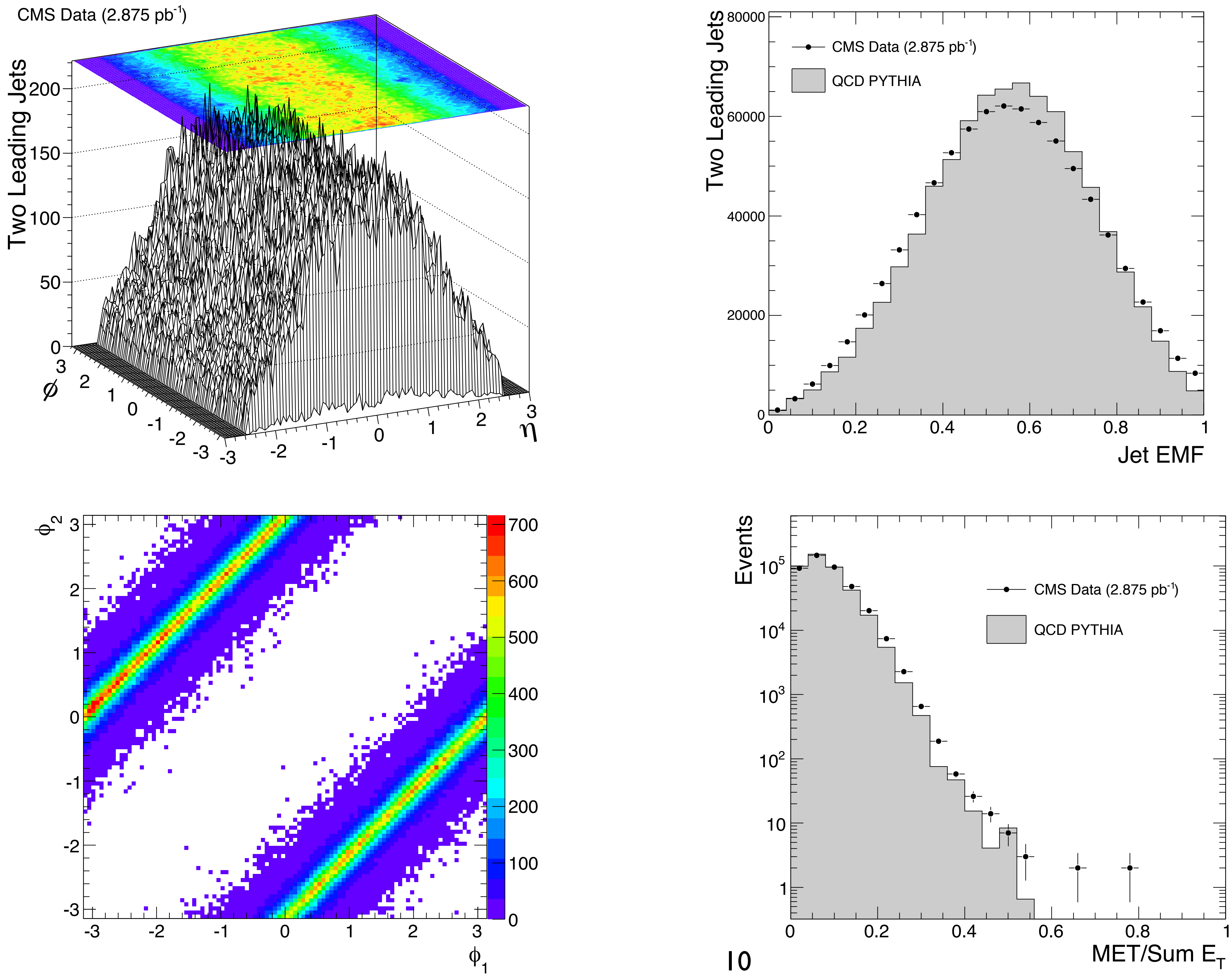
Dijet Data Quality



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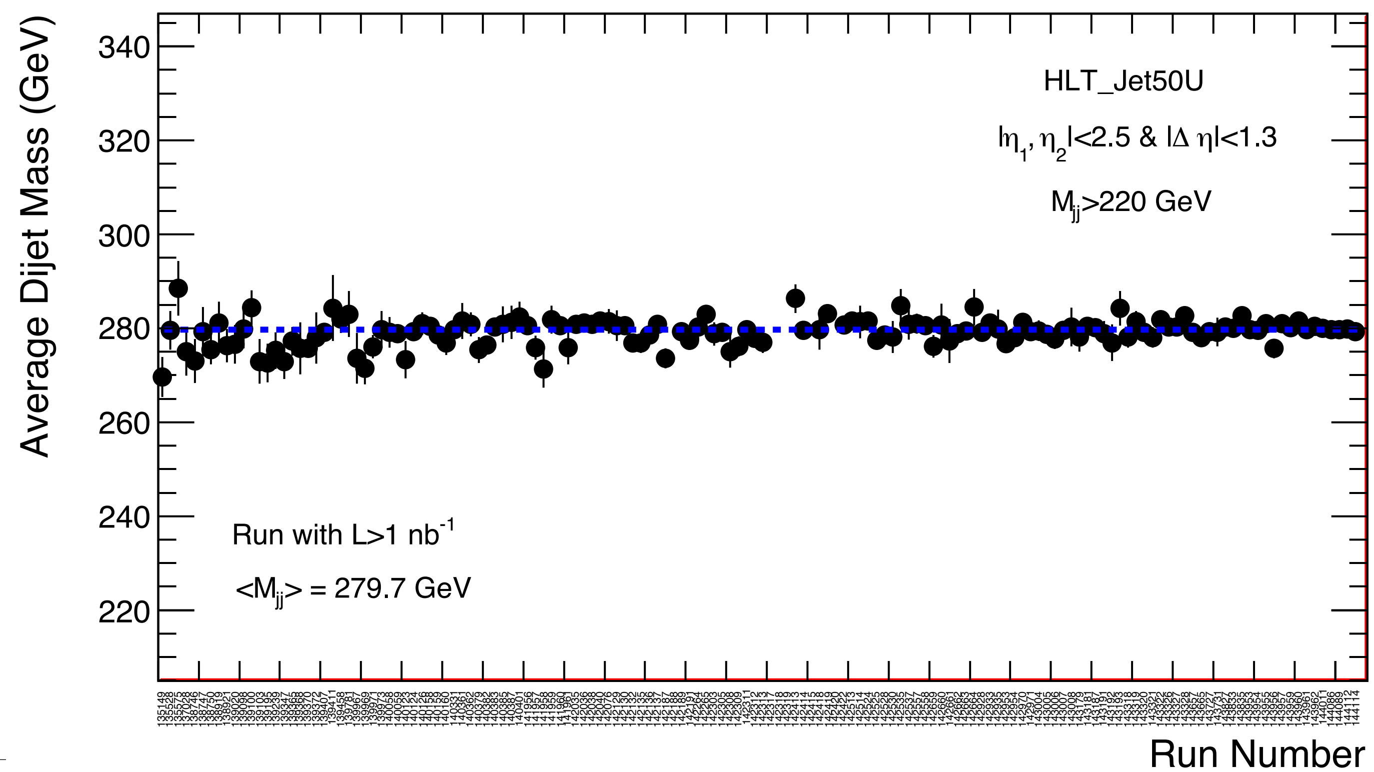
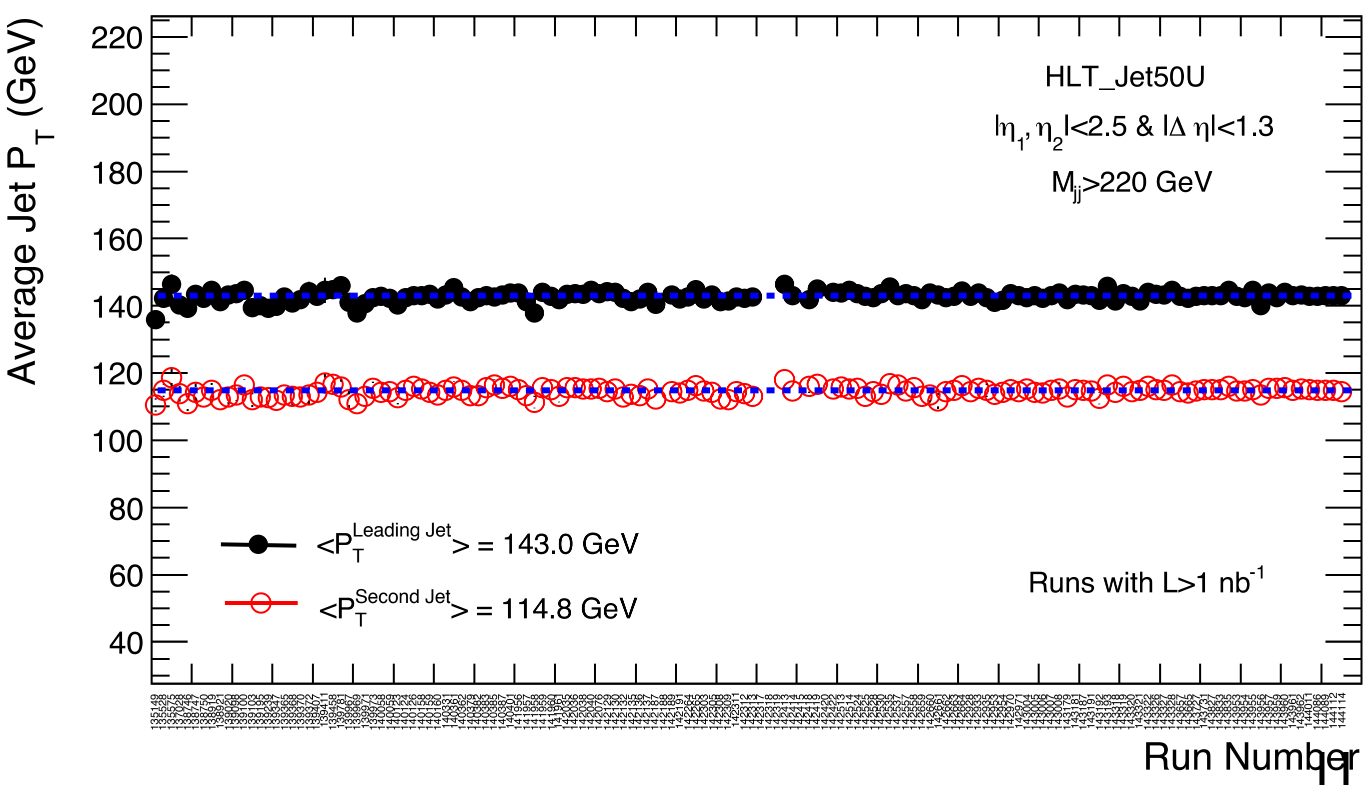
Dijet Data Stability

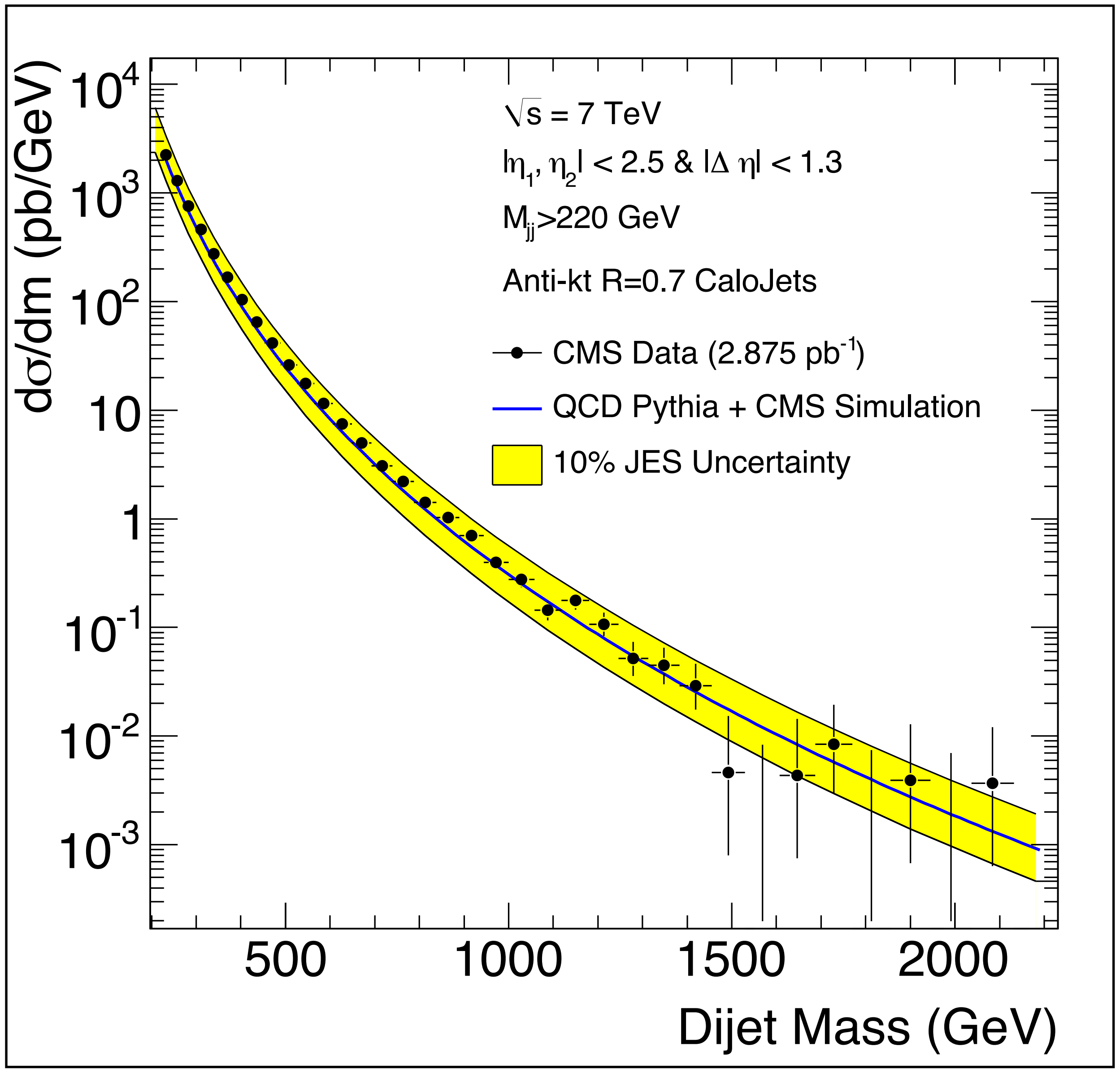


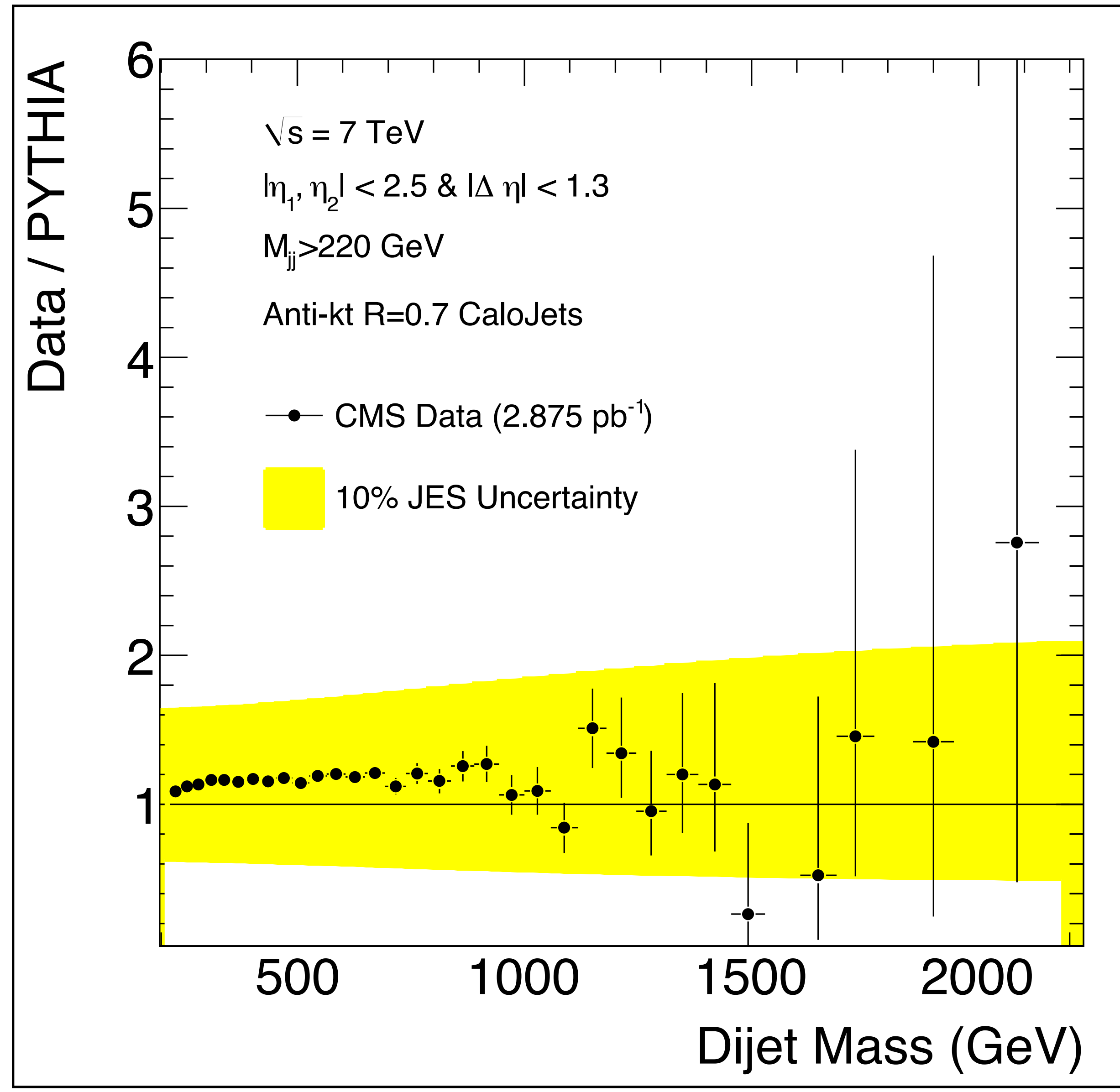


- Average dijet mass and average pt of two leading jets for each runs are shown.
- There is a good stability.

Dijet Mass and QCD

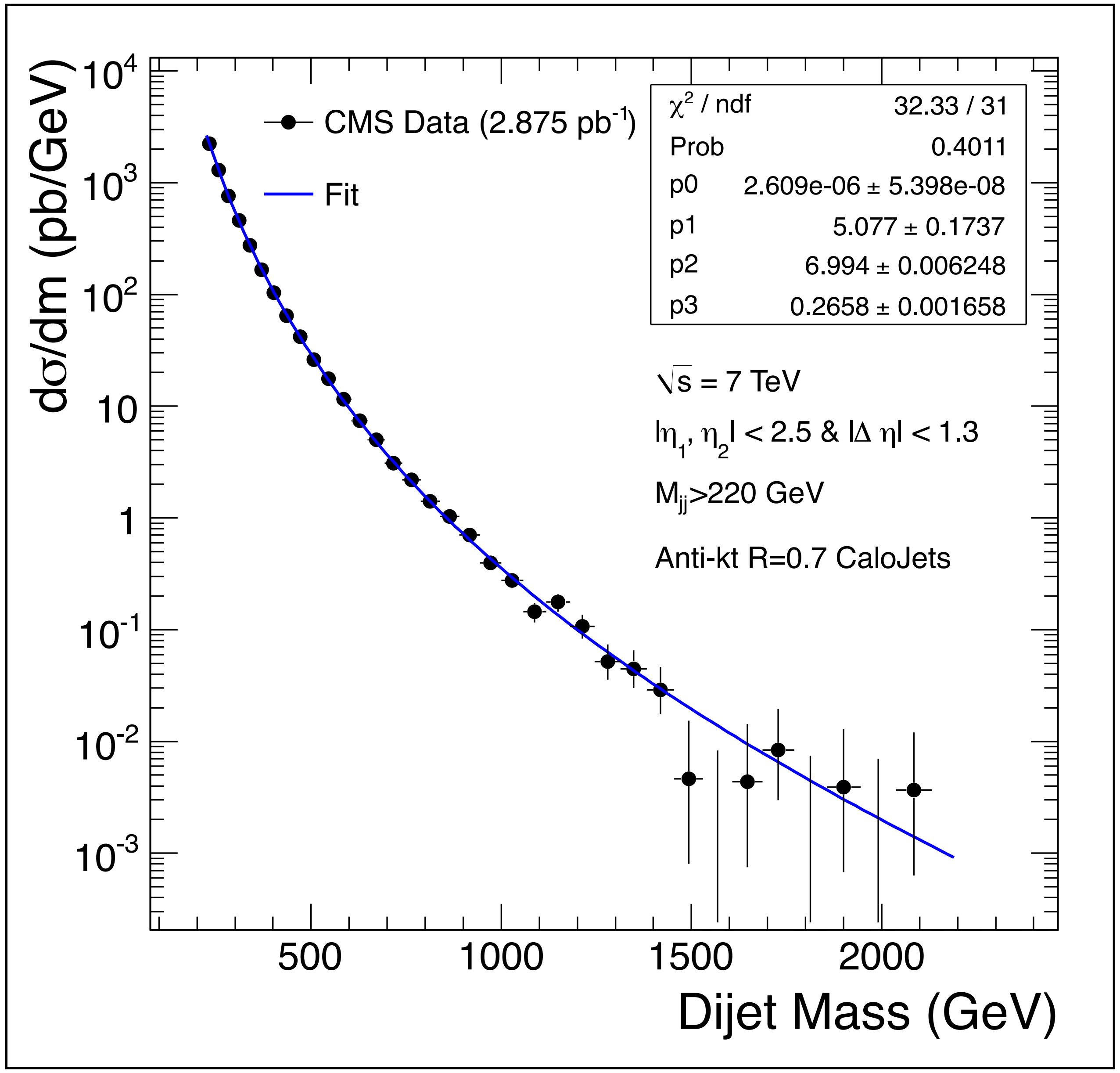
- The data is in good agreement with the full CMS simulation of QCD from PYTHIA.

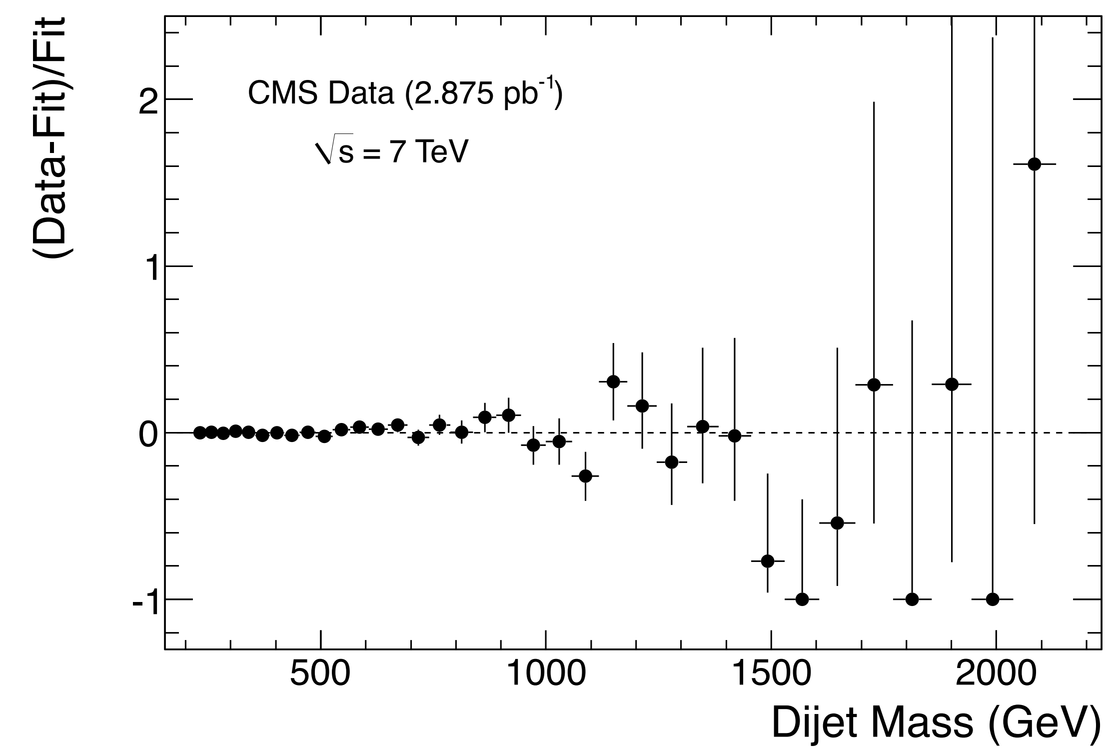


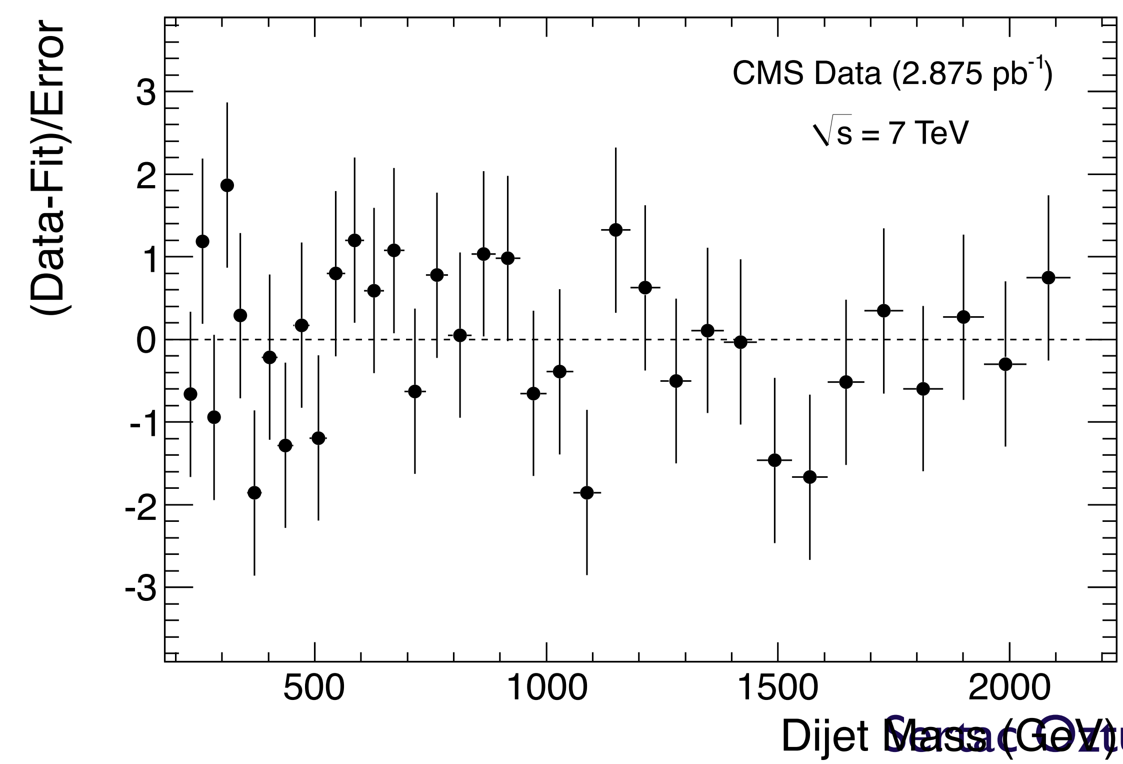


Dijet Mass and Fit

- We fit the data to a function containing 4 parameters used by CDF Run II

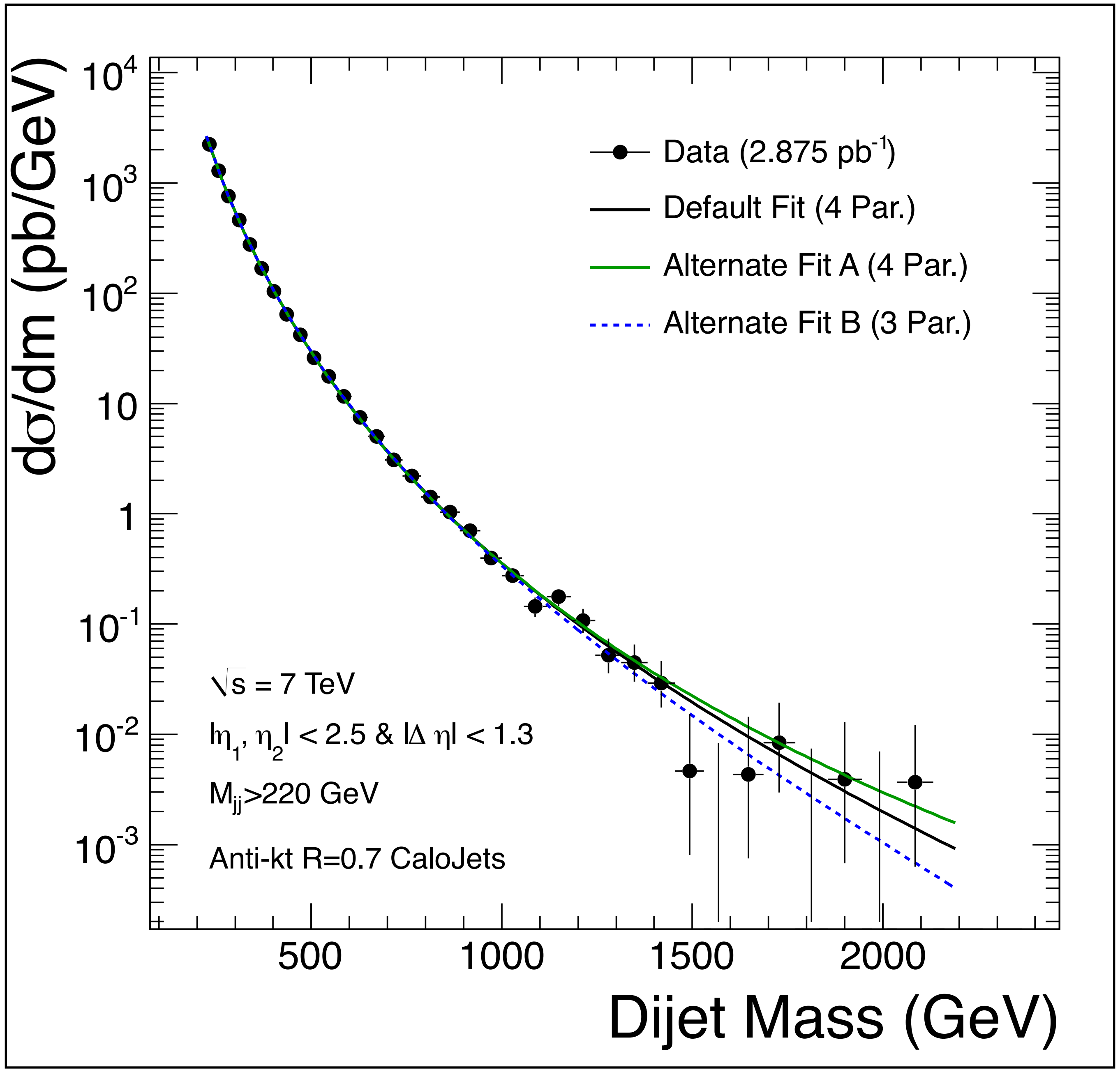






$$\frac{d\sigma}{dm} = p_0 \frac{(1-X)^{p_1}}{X^{p_2+p_3\ln(X)}} \qquad x = m_{jj}/\sqrt{s}$$

Another Fit Parametrization



χ^2/NDF for Default Fit: 32.3 / 31
χ^2/NDF for Fit A: 36.8 / 31
χ^2/NDF for Fit B: 39.3 / 32

- In addition to the default fit, 2 alternate functional forms are considered.
- Default 4 parameters fit gives best result.

Default

$$\frac{P_0 \cdot (1 - m/\sqrt{s})^{p_1}}{(m/\sqrt{s})^{p_2 + p_3 ln(m\sqrt{s})}}$$

Fit A

$$\frac{P_0 \cdot \left(1 - m/\sqrt{s} + P_3 \cdot (m/\sqrt{s})^2\right)^{P_1}}{m^{P_2}}$$

Fit B

$$\frac{P_0 \cdot (1 - m/\sqrt{s}\,)^{P_1}}{m^{P_2}},$$

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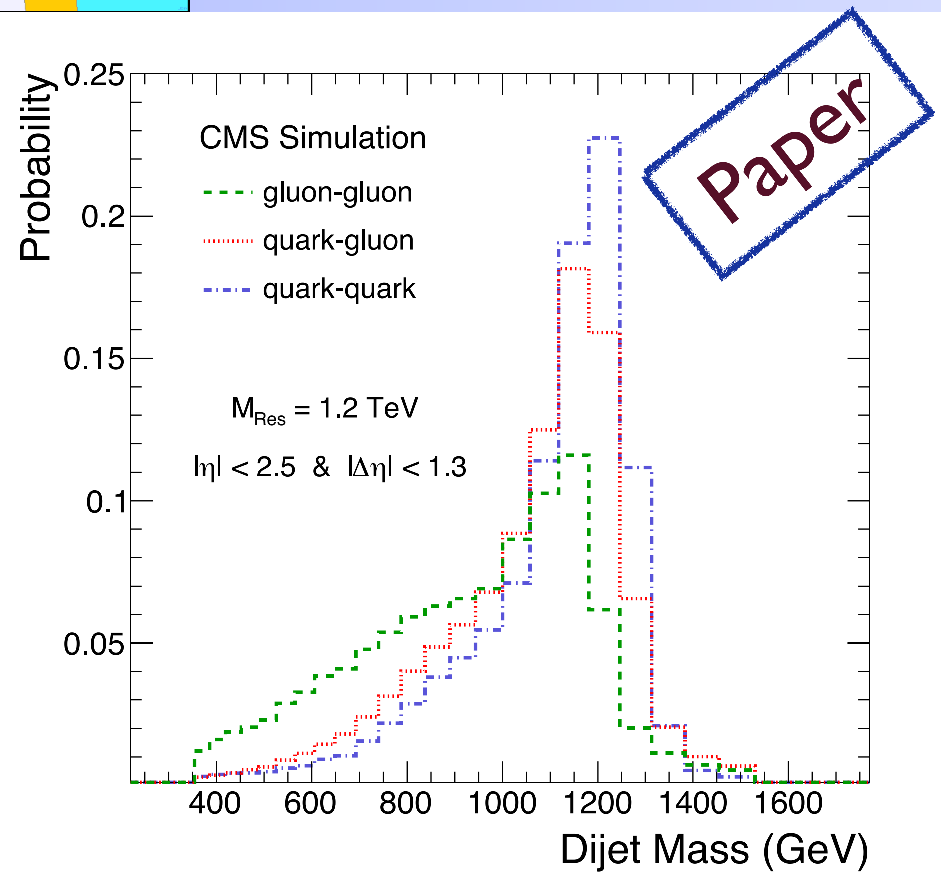
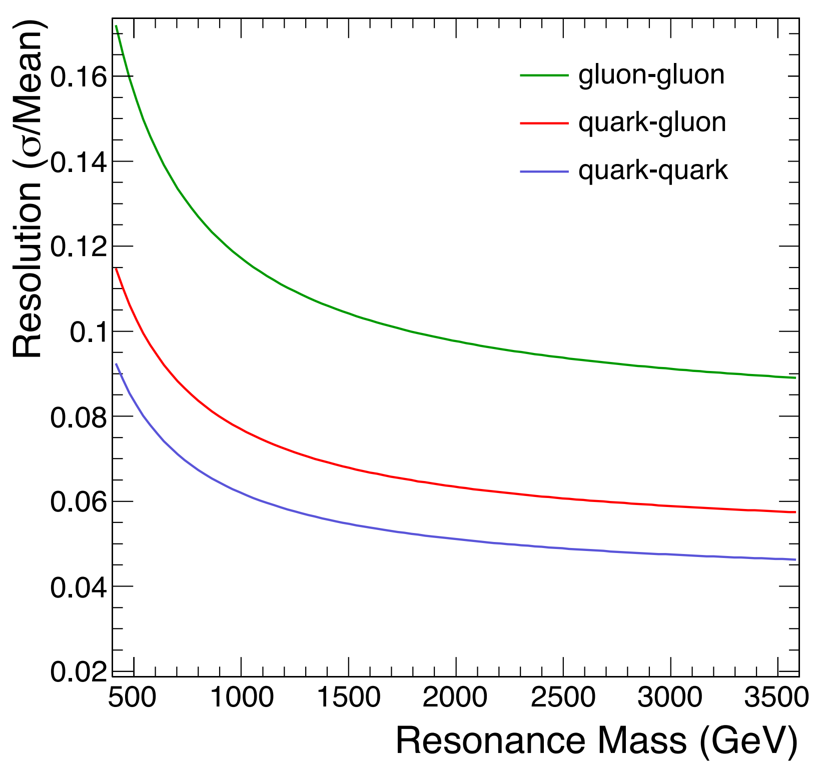
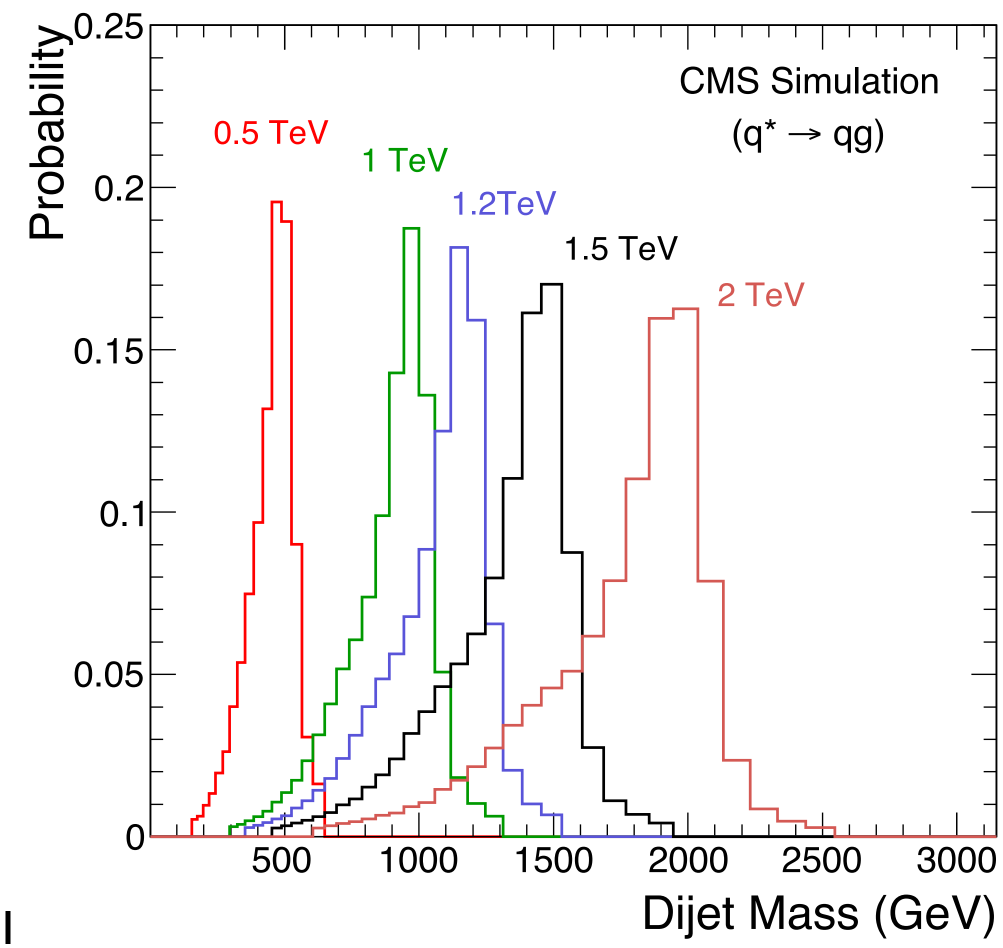
Resonance Shapes



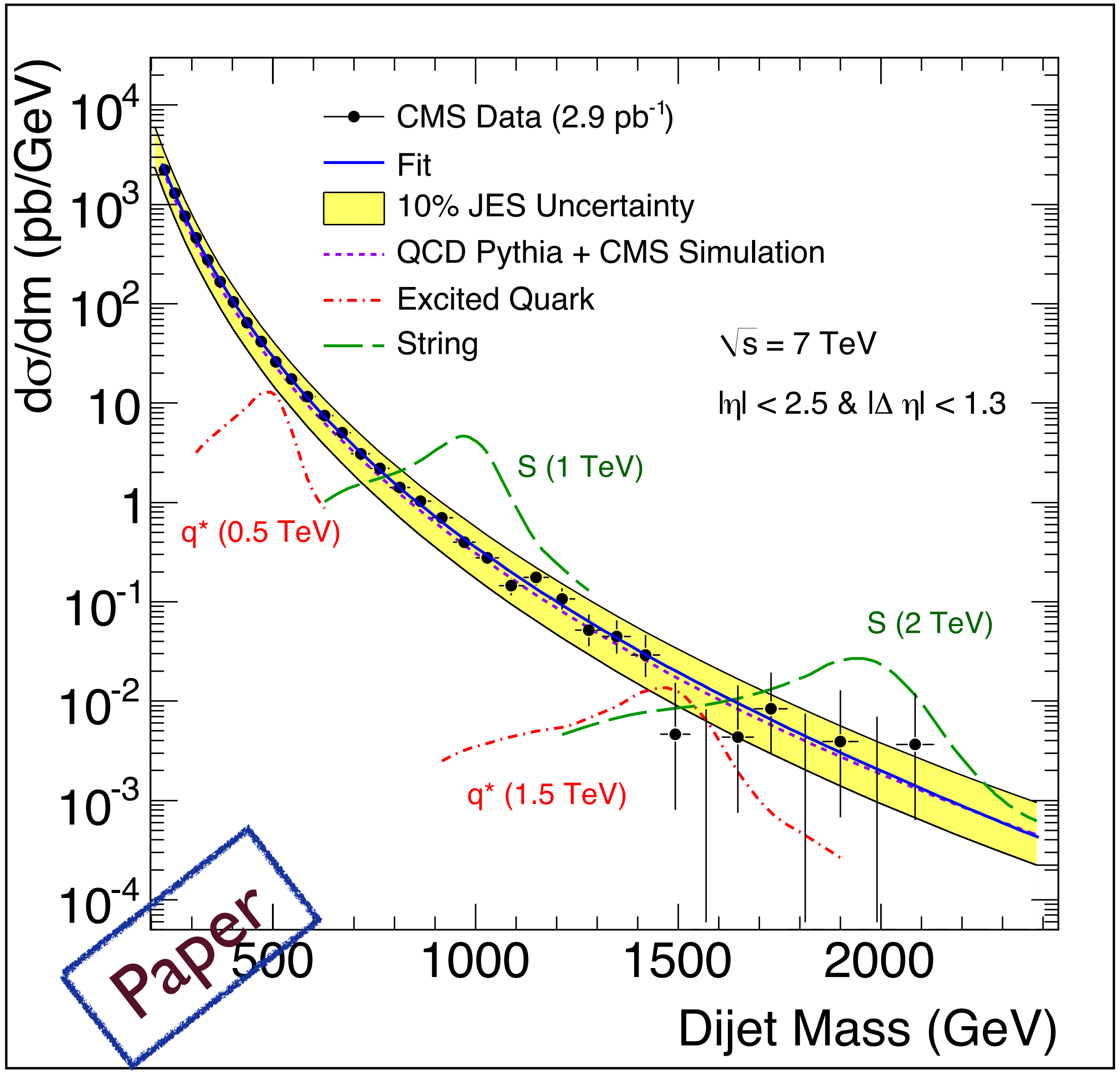
- We have simulated dijet resonances using CMS simulation + PYTHIA.
- qq, qg and gg resonances have different shape mainly due to FSR.
  - ✓ The width of dijet resonance increases with number of gluons because gluons emit more radiation than quarks.
- We search for these three basic types of narrow dijet resonance in our data.

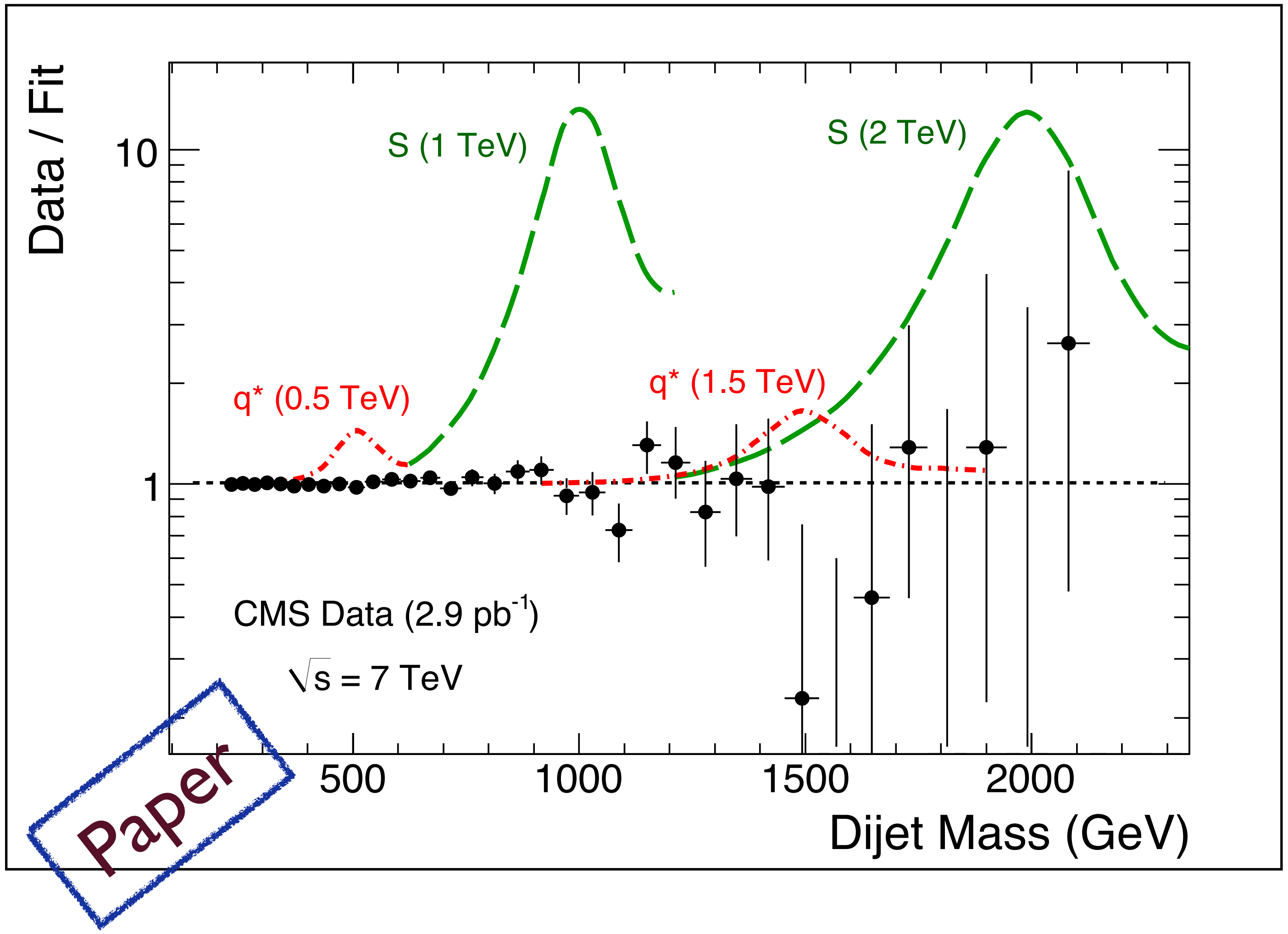




Fit and Signal

- We search for dijet resonance signal in our data.
- Excited quark signals are shown at 0.5 TeV and 1.5 TeV.
- String resonance is shown at 1 TeV and 2 TeV.





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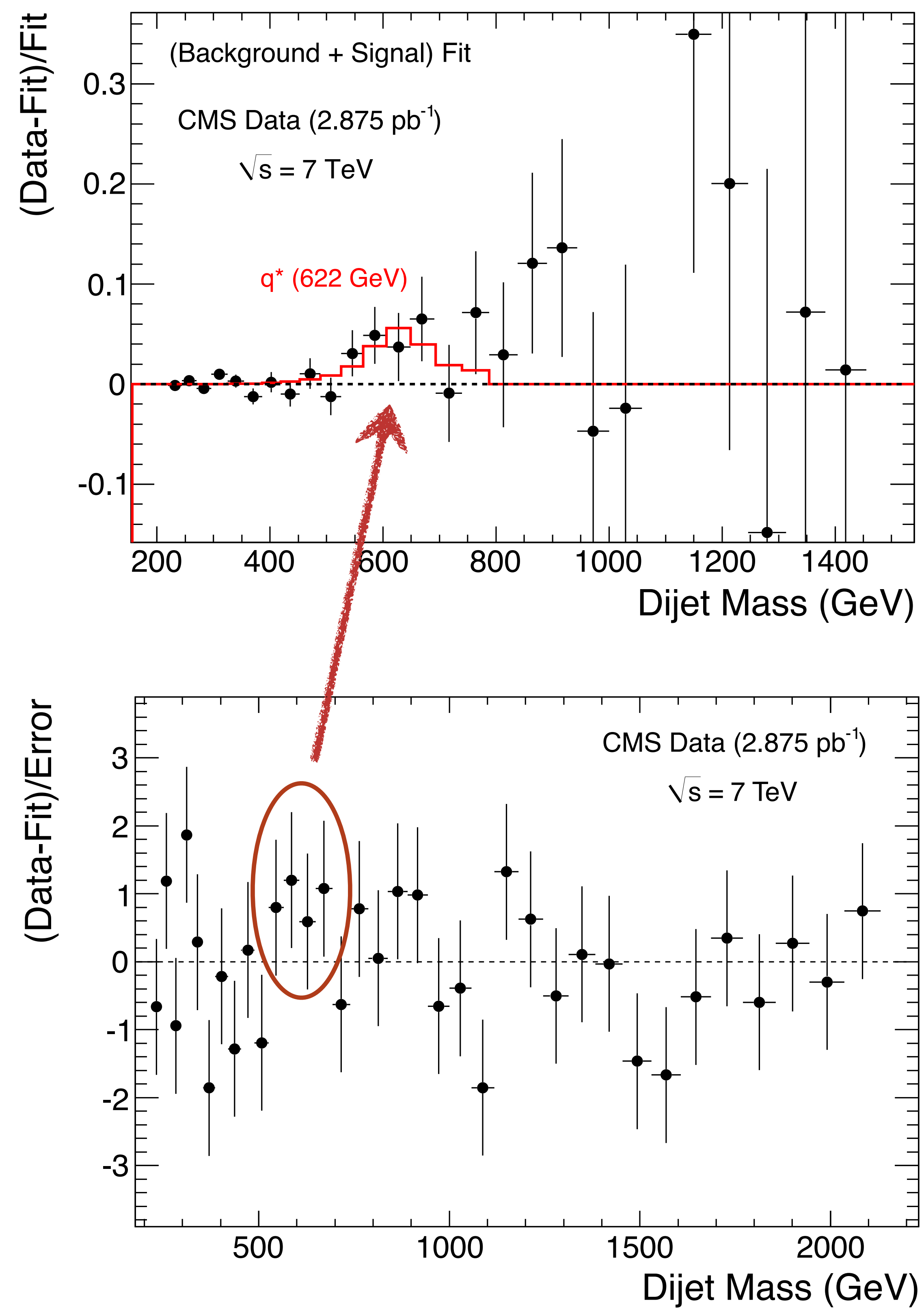
The Largest Fluctuation in Data

- Upward fluctuations around 600 GeV and 900 GeV
- Best fit resonance is at 622 GeV with local significance 1.86 sigma from log likelihood ratio.
- There is no evidence for dijet resonance.



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Setting Limits

- For setting upper limit on the resonance production cross section, a Bayesian formalism with a uniform prior is used.

$$L = \prod_i \frac{\mu_i^{n_i} e^{-\mu_i}}{n_i!} \qquad \mu_i = \alpha N_i(S) + N_i(B).$$

Measured # of events in data (n_i)

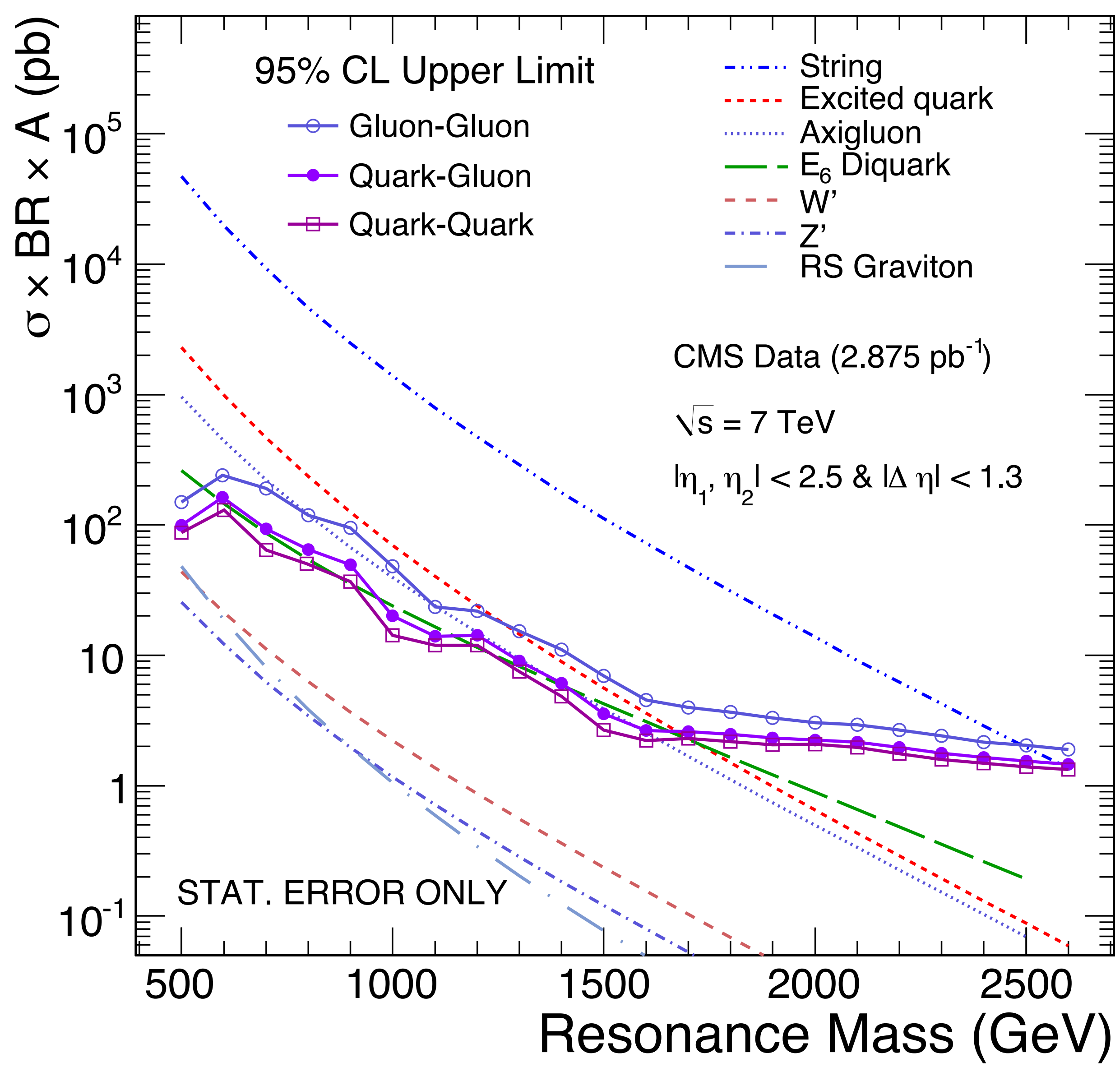
# of event from signal ($N_i(S)$)

Expected # of event from background ($N_i(B)$)

- The signal comes from our dijet resonance shapes.
- The background comes from Background+Signal fit.

Early Limits with Stat. Error Only

- 95% CL Upper limit with Stat. Error. Only compared to cross section for various model.
  - ✓ Show quark-quark and quark-gluon and gluon-gluon resonances separately.
  - ✓ gluon-gluon resonance has the lowest response and is the widest and gives worst limit.

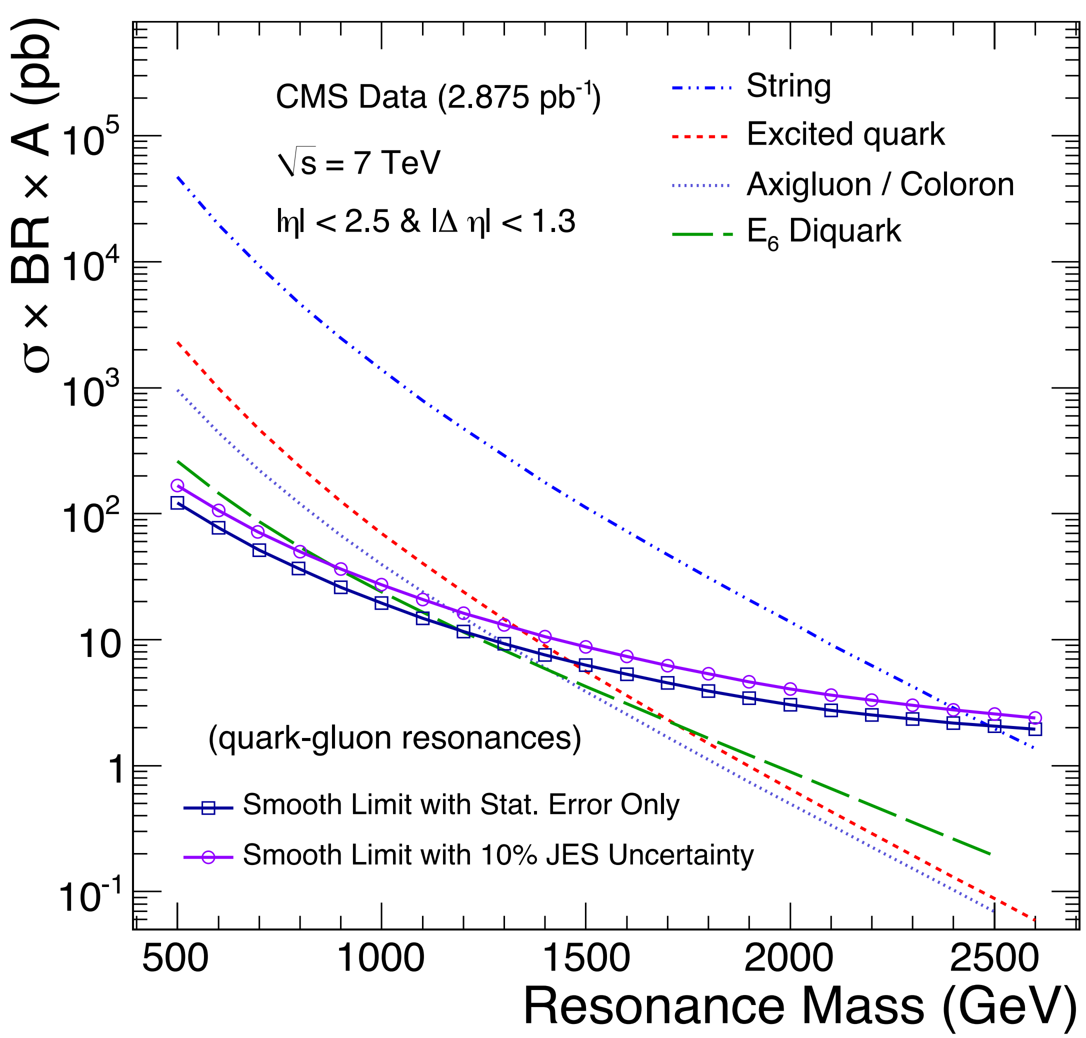


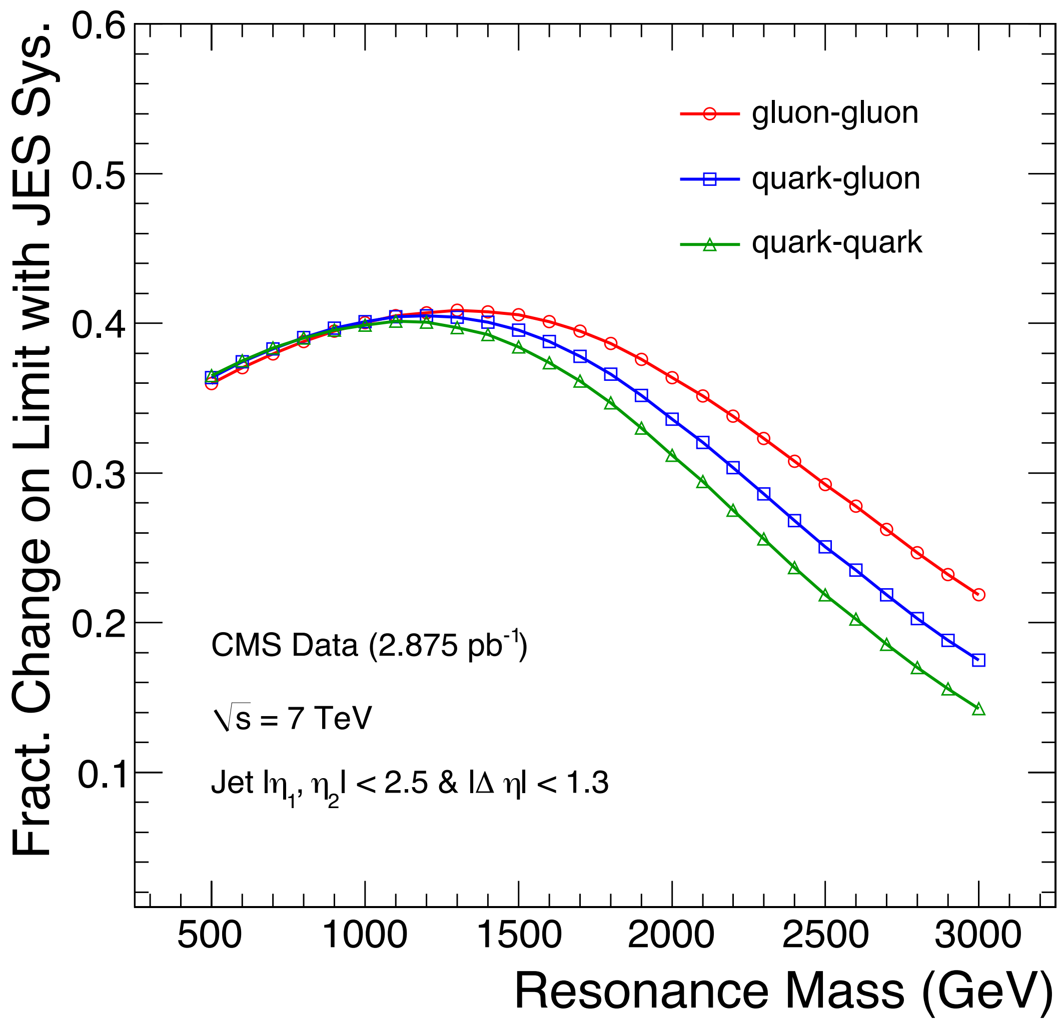
Systematics

- We found the uncertainty in dijet resonance cross section from following sources.
  - ✓ Jet Energy Scale (JES)
  - ✓ Jet Energy Resolution (JER)
  - ✓ Choice of Background Parametrization
  - ✓ Luminosity

Jet Energy Scale (JES)

- JetMET guidance is 10% uncertainty in jet energy scale.
  - ✓ Shifting the resonance 10% lower in dijet mass gives more QCD background
  - ✓ Increases the limit between 14% and 42% depending on resonance mass and type.





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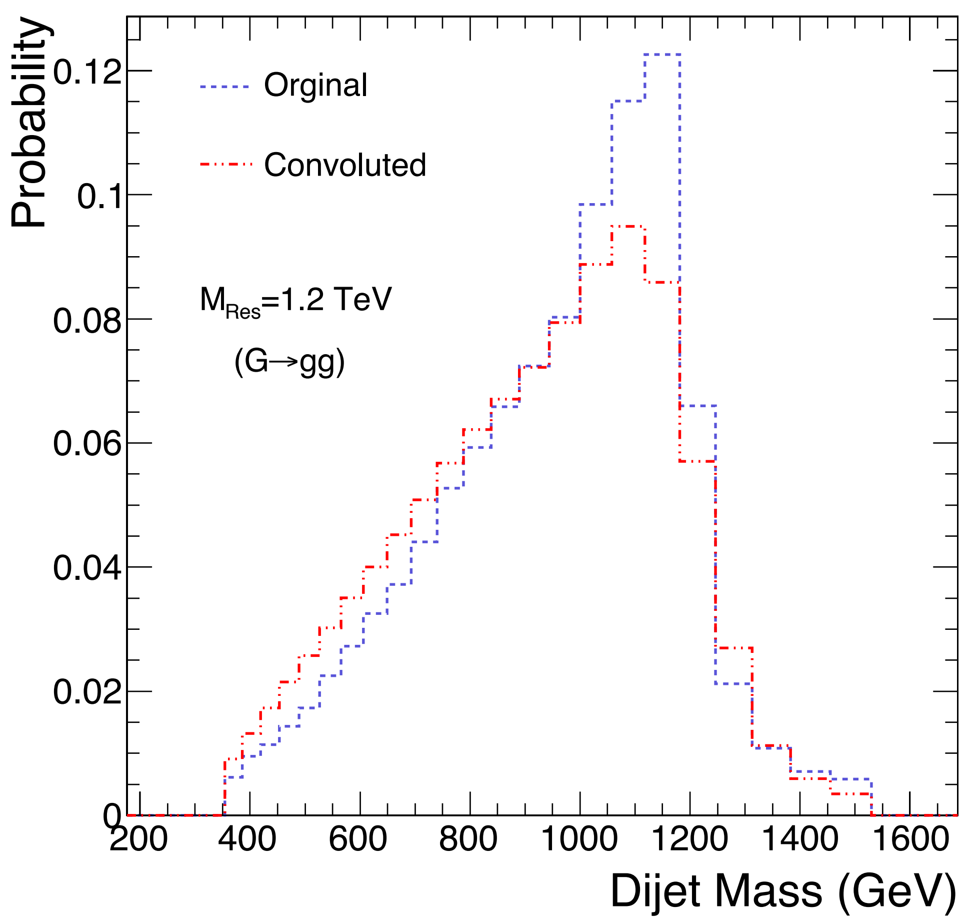
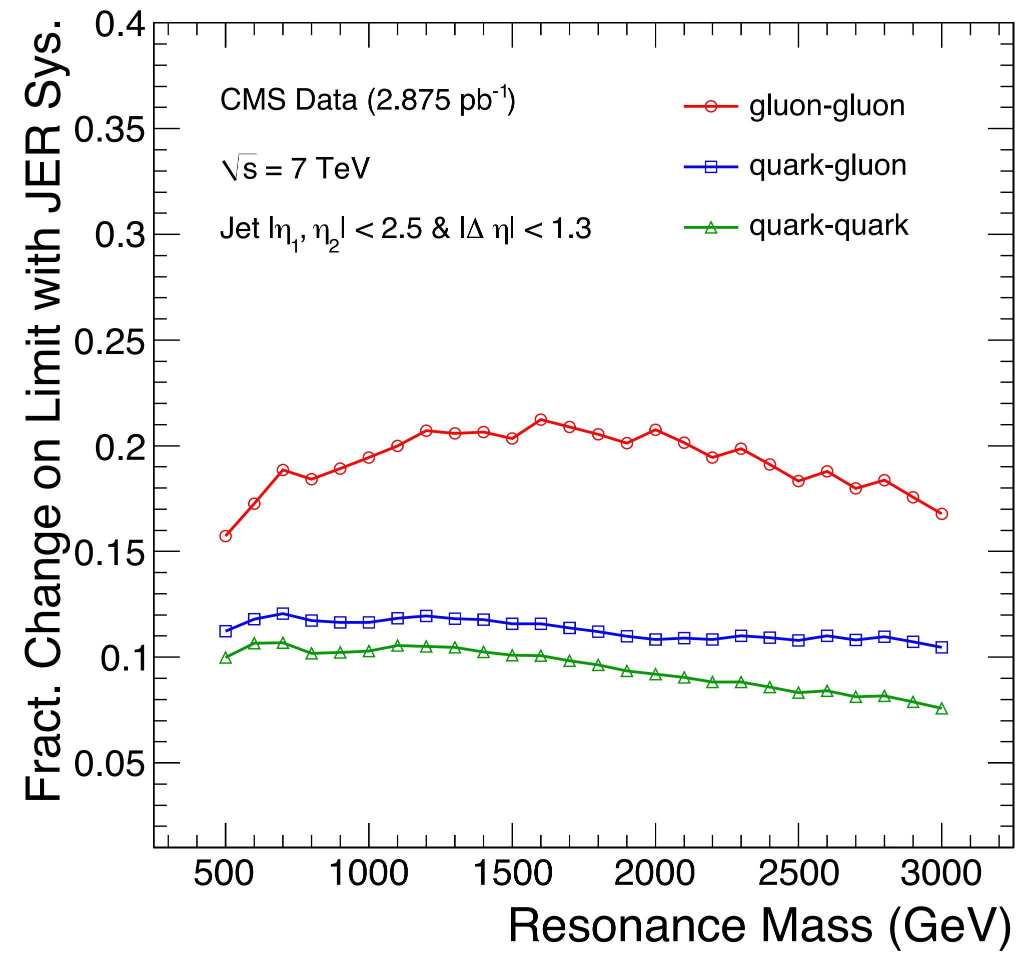
Jet Energy Resolution (JER)

- JetMET guidance is 10% uncertainty in jet energy resolution.
- We smear our resonance shapes with a gaussian designed to increase the core width by 10%.
  - ✓ $\sigma_{Gaus} = \sqrt{(1.1)^2-1}\,\sigma_{Res}$
- This increases our limit between 7% and 22% depending on resonance mass and type.





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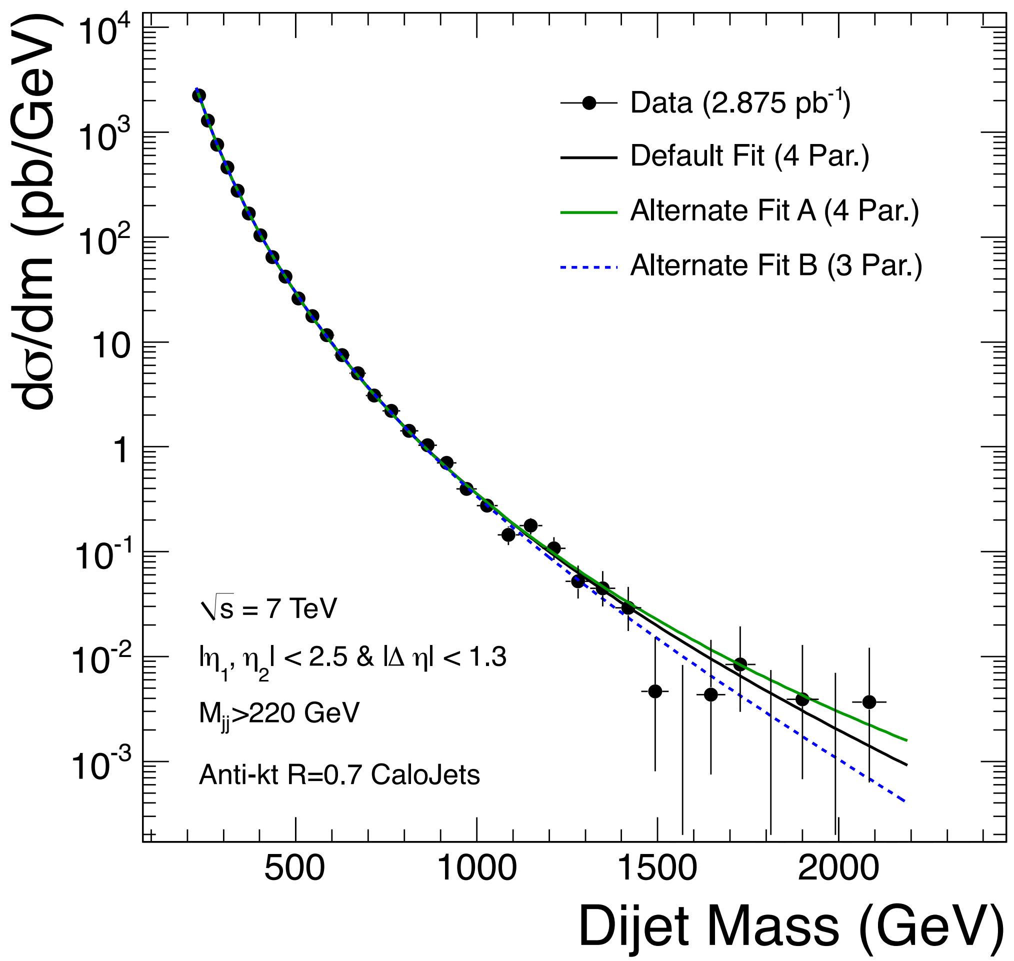
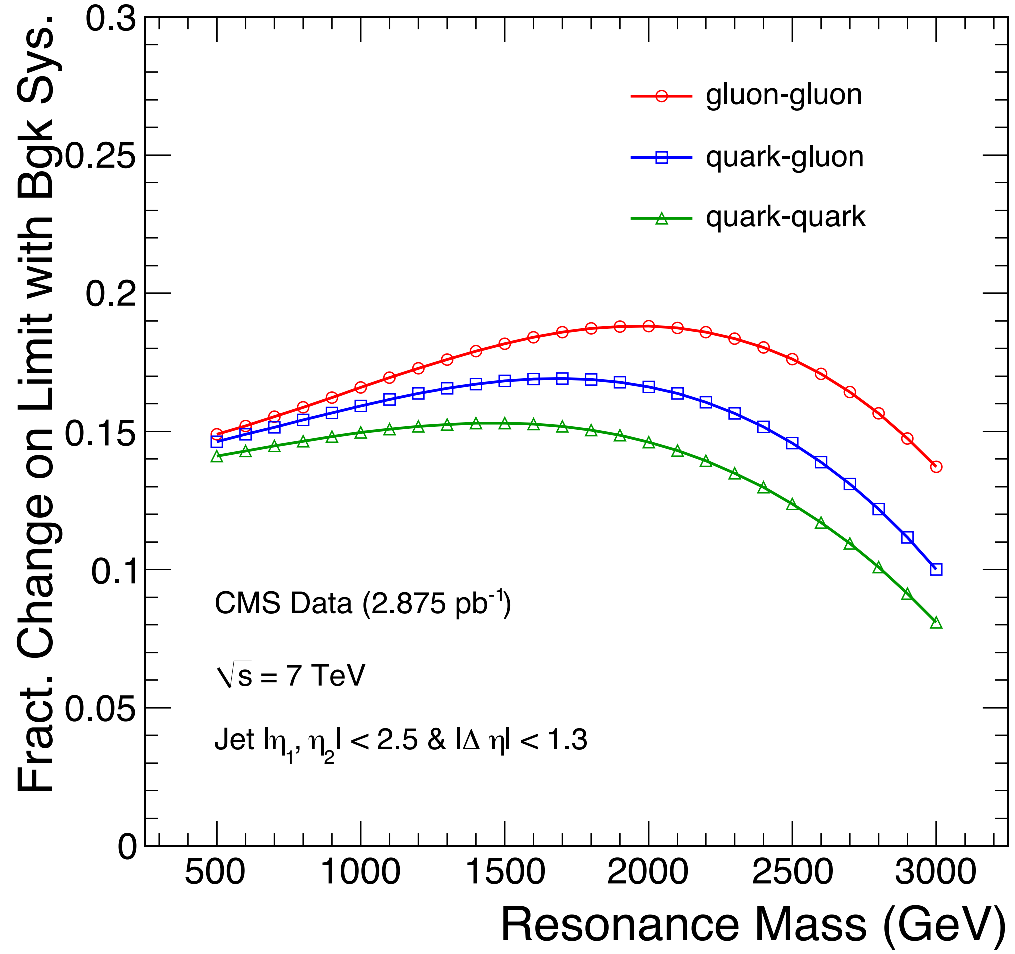
Background Parametrization Systematics

- We have varied the choice of background parametrization
- We use the 4 parameter fit as a systematic on our background shape.
- This increases our limit between 8% and 19% depending on resonance mass and type.





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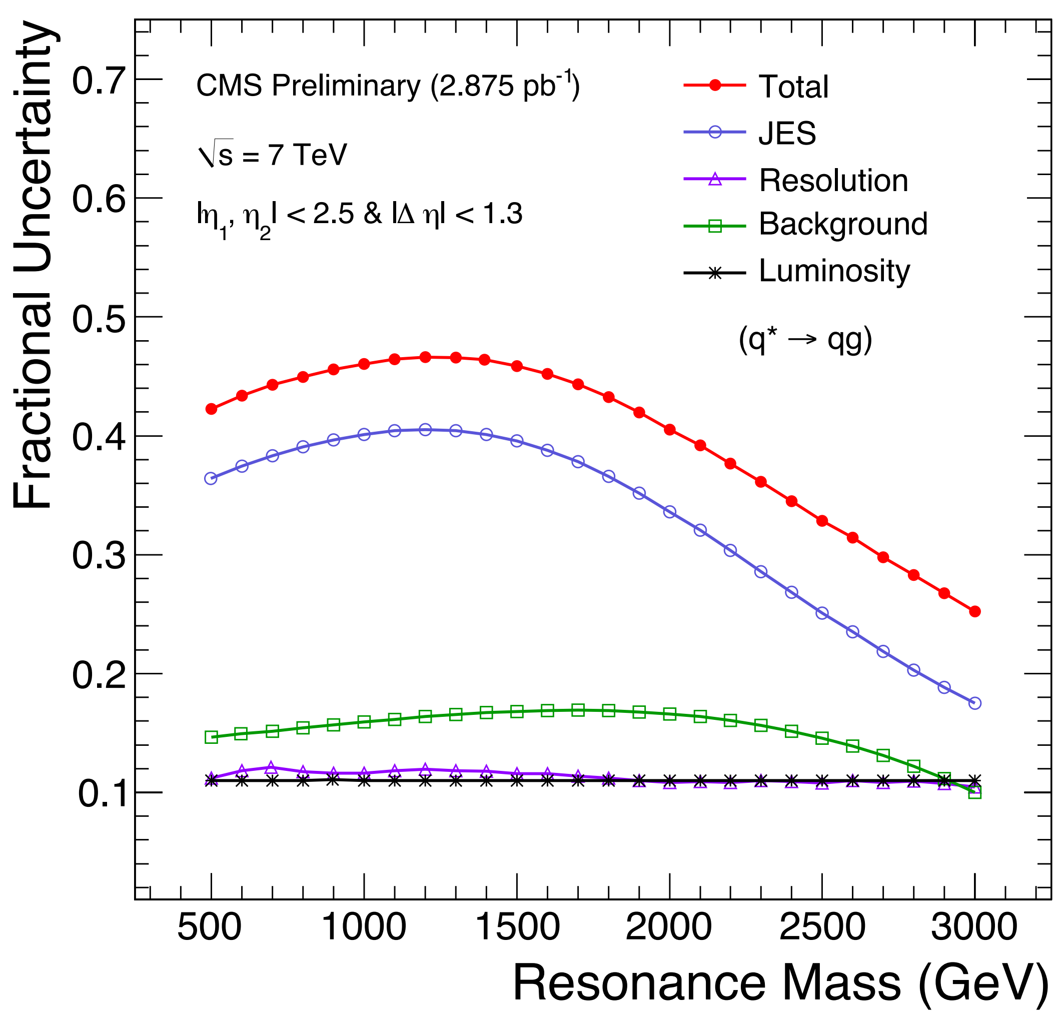
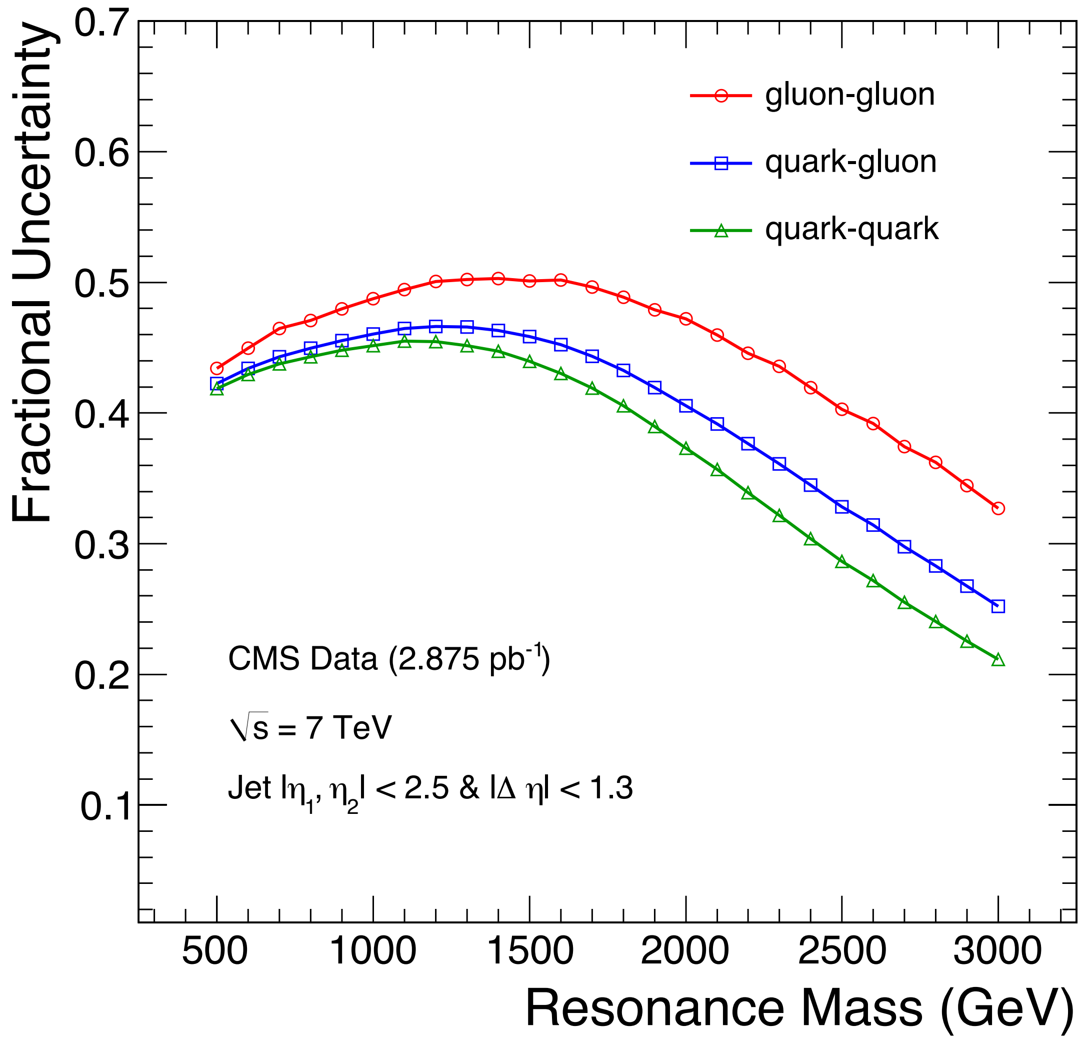
Total Systematic Uncertainties

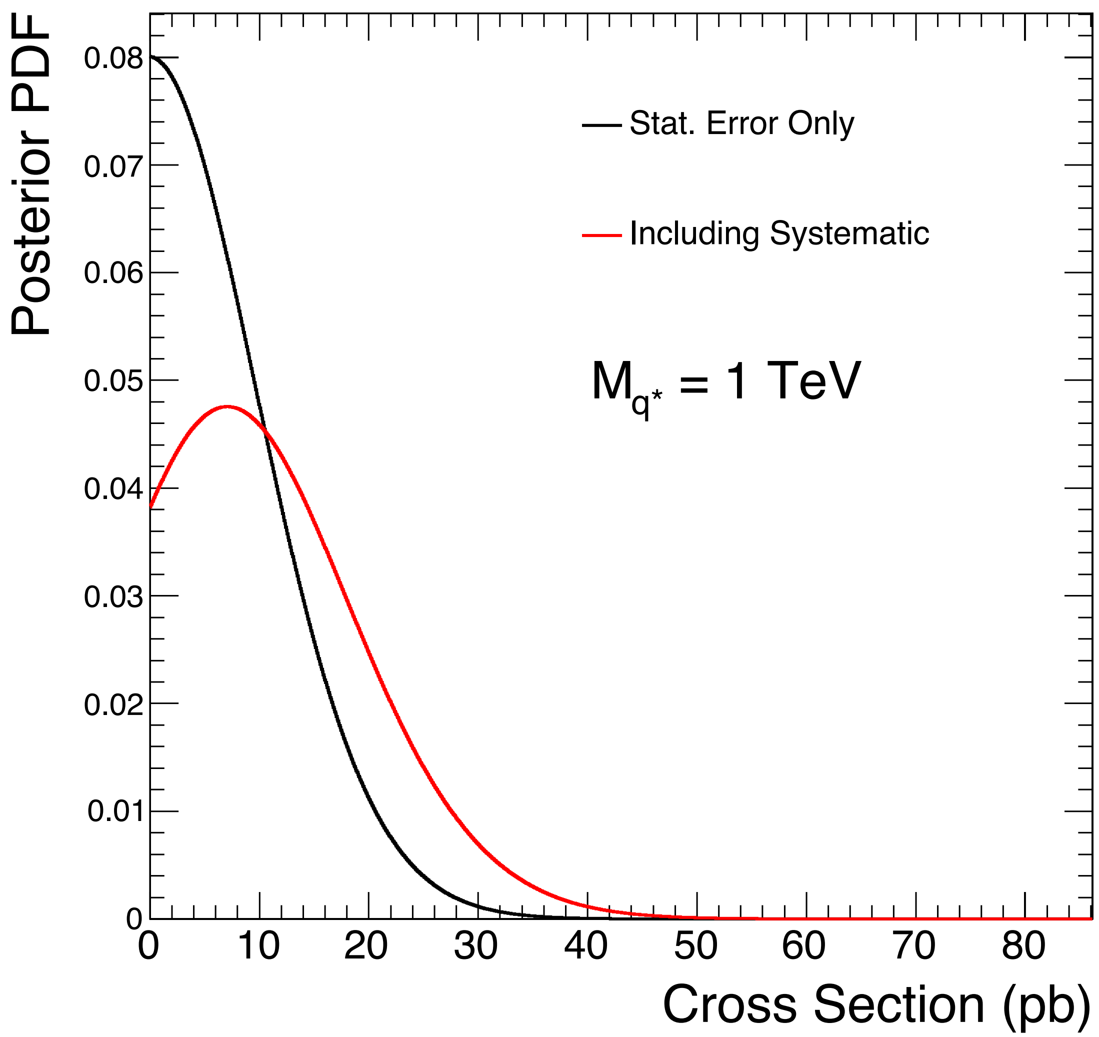
- We add all mentioned systematic uncertainties in quadrature, also 11% for luminosity.
- JEC is dominant systematic uncertainty.
- Total systematic uncertainty varies from 24% to 48% depending on resonance mass and type.





Incorporating Systematic

- We convolute posterior PDF with Gaussian systematics uncertainties.
  - ✓ Posterior PDF including systematics is broader and gives higher upper limit.



$$L(\sigma) = \int_0^\infty L(\sigma')G(\sigma,\sigma')d\sigma'$$

G: Gaussian distribution with RMS width equal to systematic uncertainty in cross section

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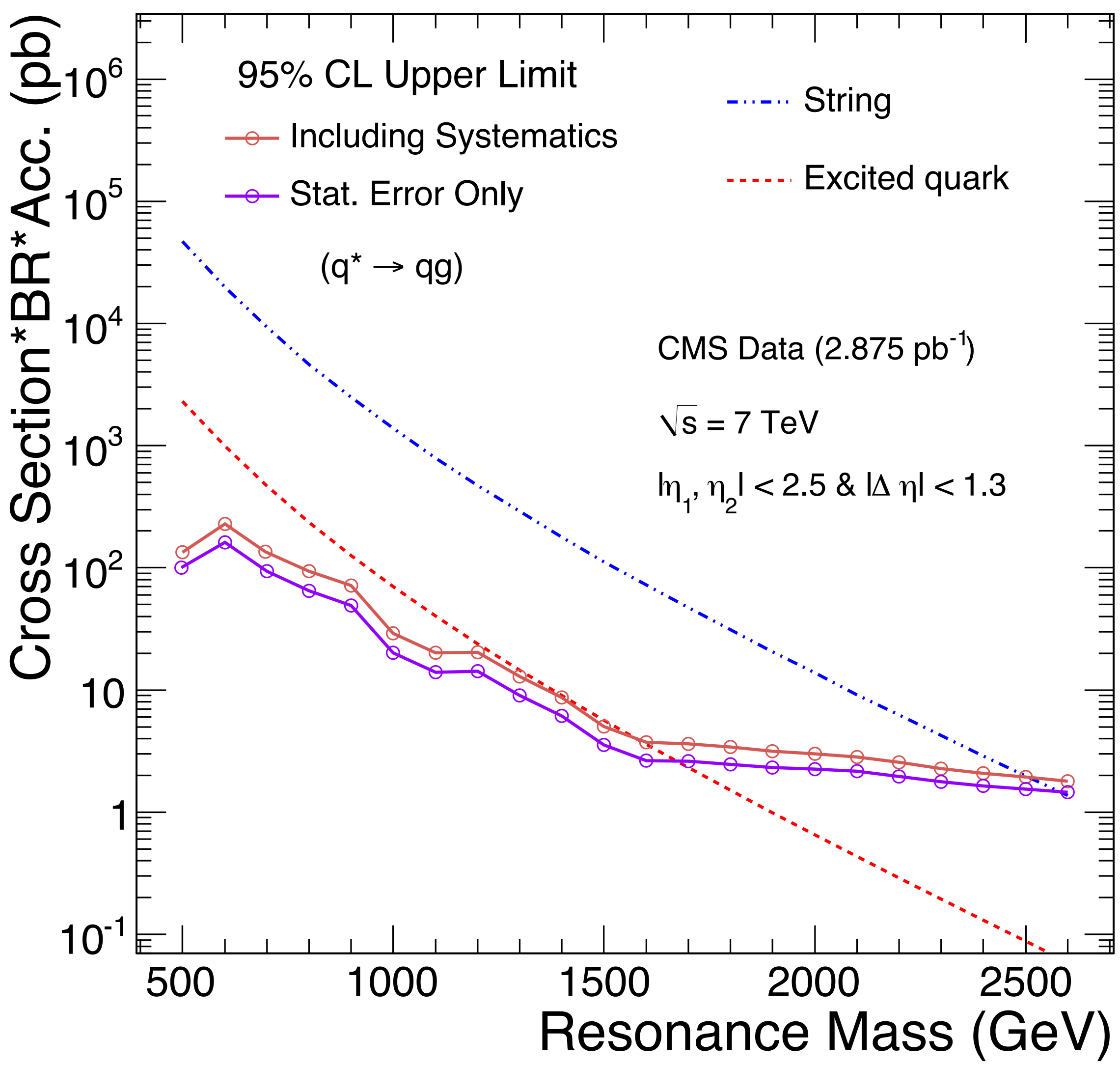
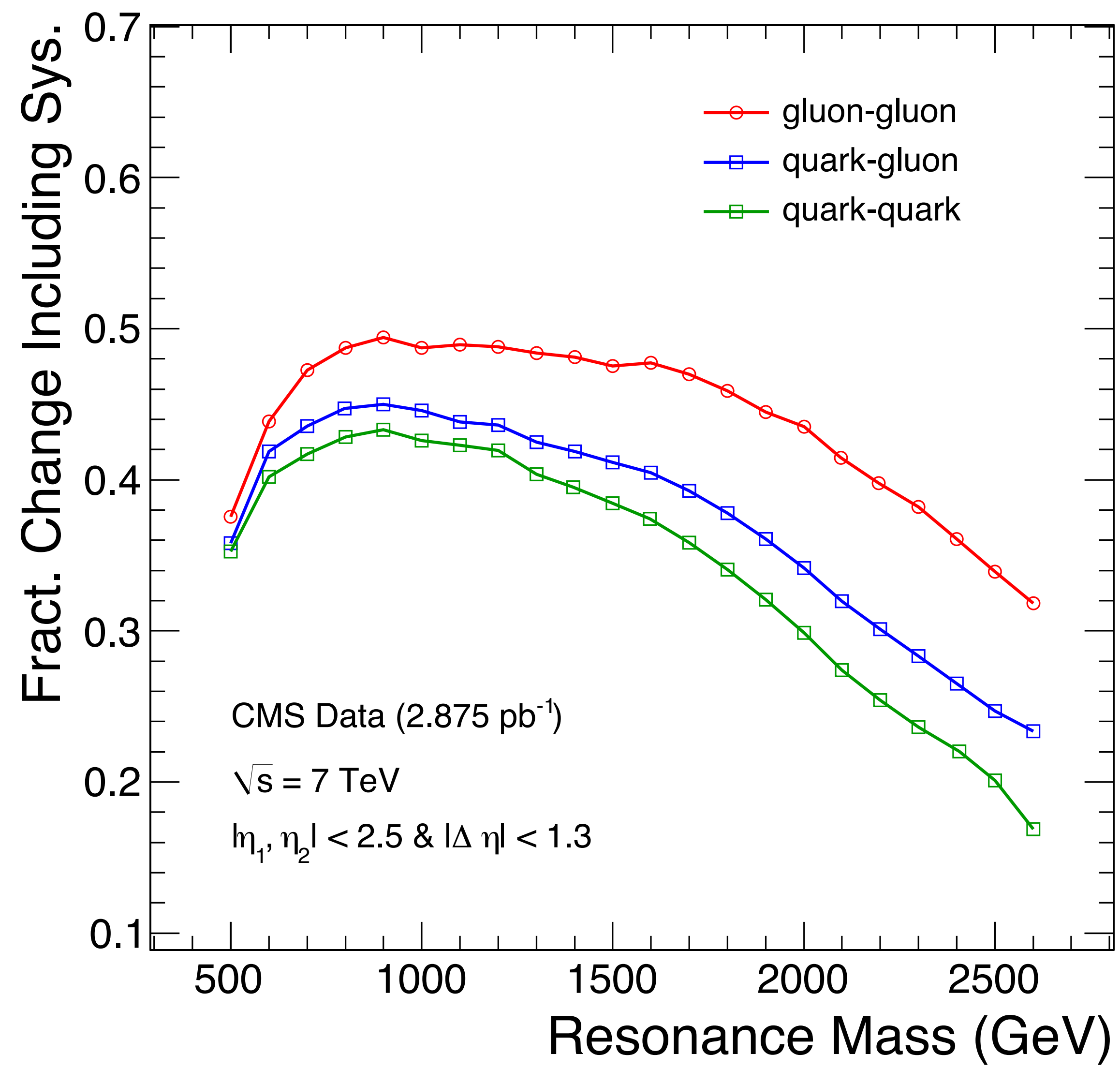
Effect of Systematics on Limit

- 95% CL Upper limit with Stat. Error. Only and Including Sys. Uncertainties are shown separately.
- The mass limits are reduced by 0.1 TeV for both string resonance and excited quark.





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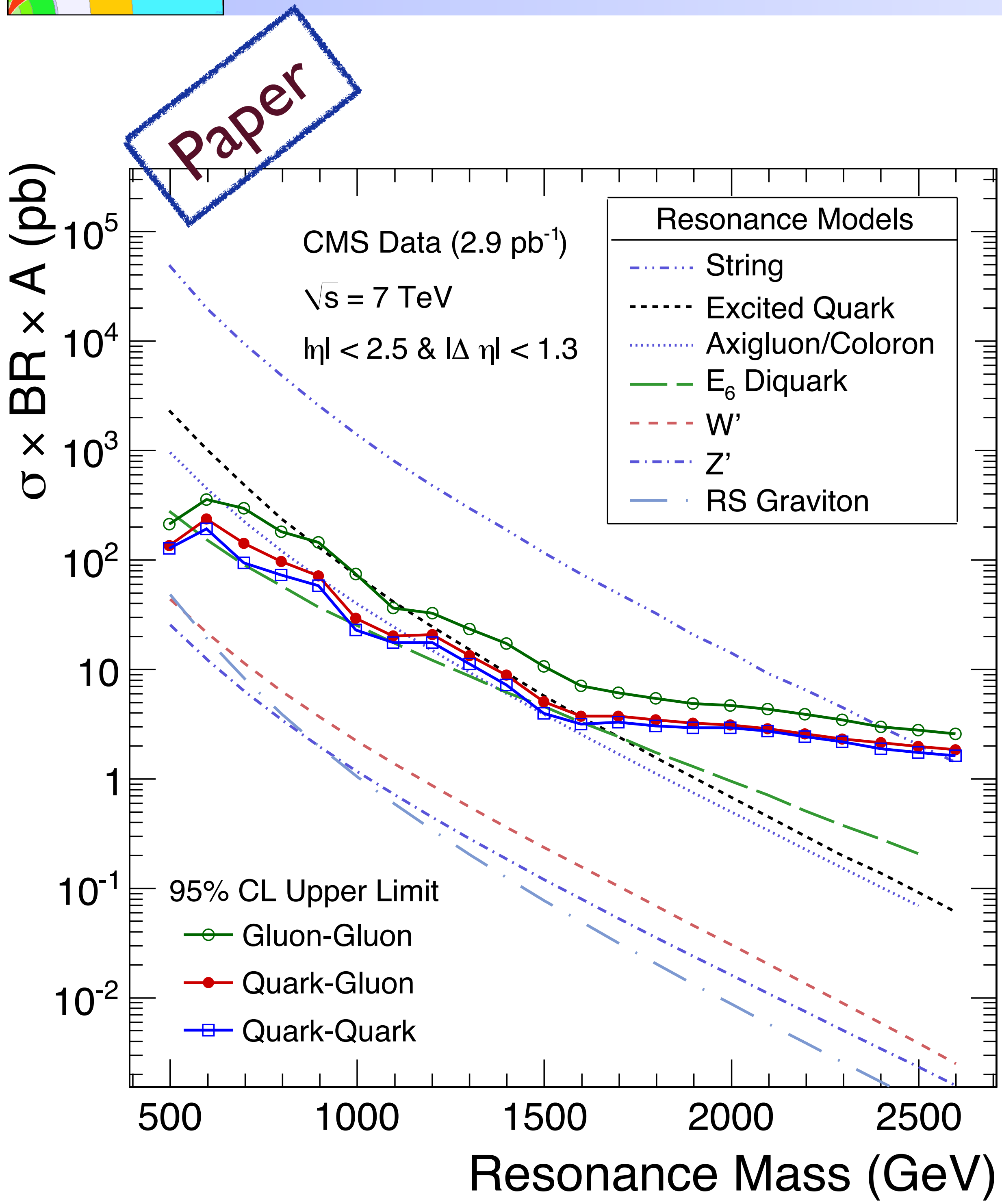
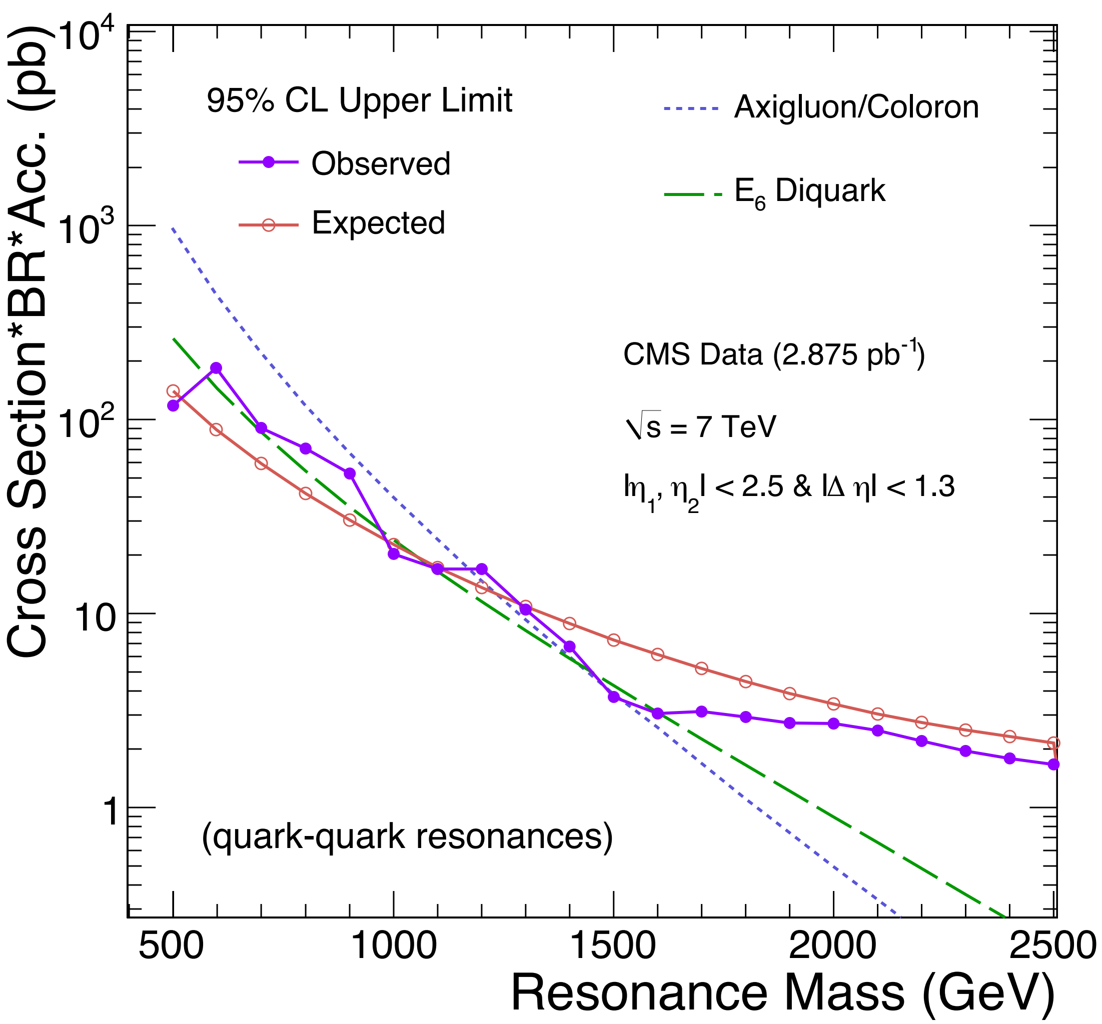
Results

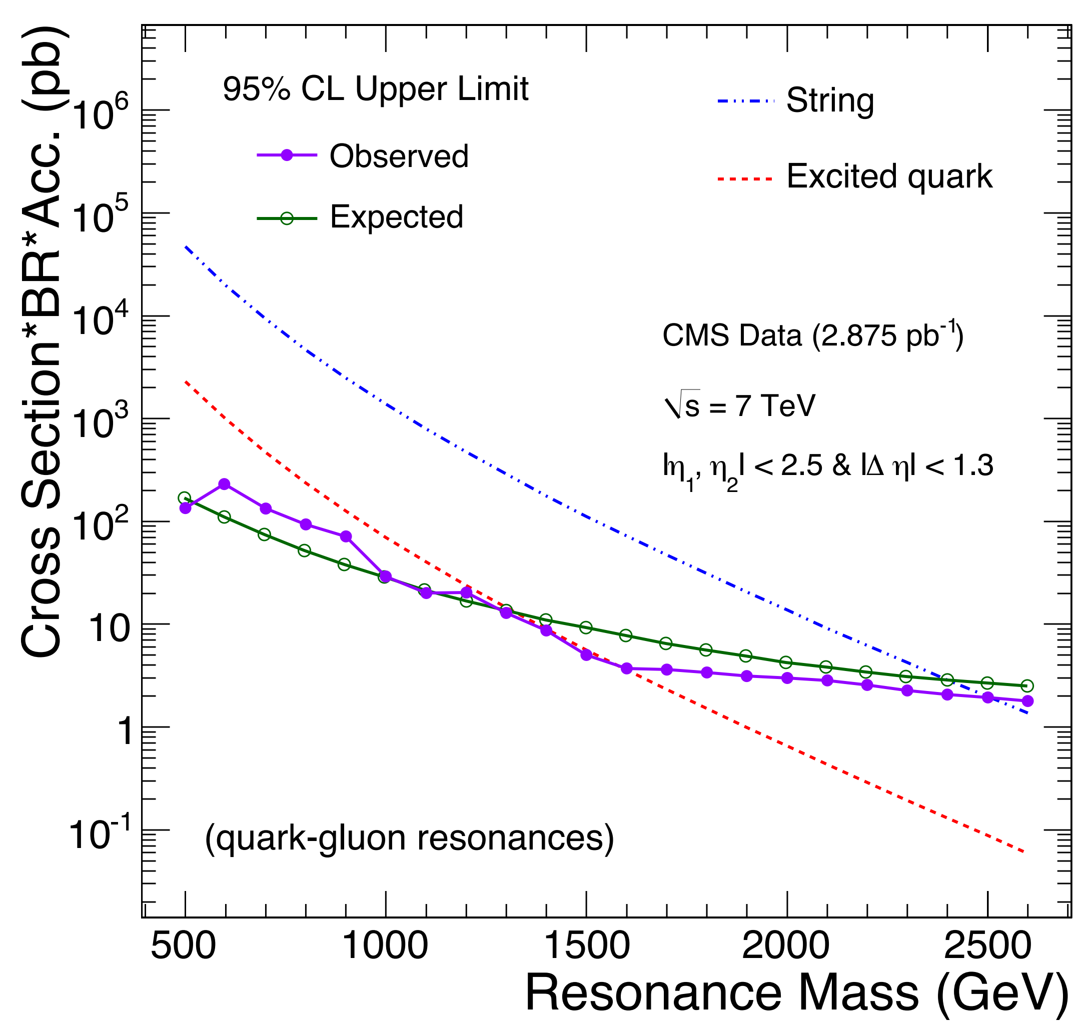


- We excluded the mass limits as following:
- String
  - ✓ 0.50<M(S)<2.50 TeV
    - M(S)<1.40 from CDF
- Excited Quark
  - ✓ 0.50<M(q*)<1.58 TeV
    - 0.40<M(q*)<1.26 from ATLAS
- Axigluon/Coloron
  - ✓ 0.50<M(A)<1.17 TeV & 1.47<M(A)<1.52 TeV
    - 0.12<M(A)<1.25 TeV from CDF
- E_6 Diquark
  - ✓ 0.50<M(D)<0.58 TeV & 0.97<M(D)<1.08 TeV & 1.45<M(D)<1.60 TeV
    - 0.29<M(D)<0.63 TeV from CDF

Expected Limit

- Due to downward fluctuation around 1.2 TeV, measured limit is 250 GeV grater than expected limit for excited quark.
- Due to upward fluctuation around 600 GeV, we lost sensitivity to a E_6 diquark at low resonance mass.





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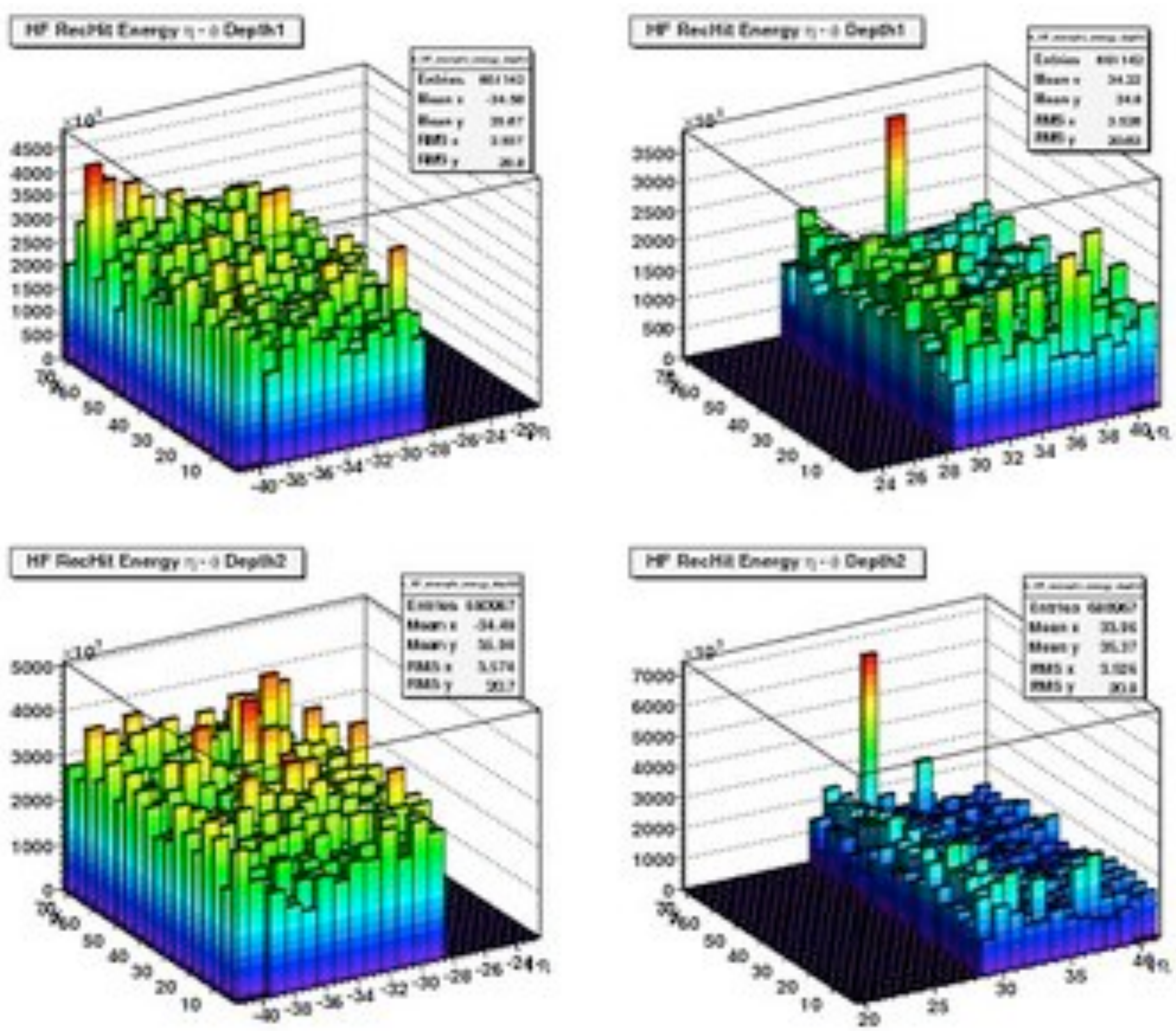
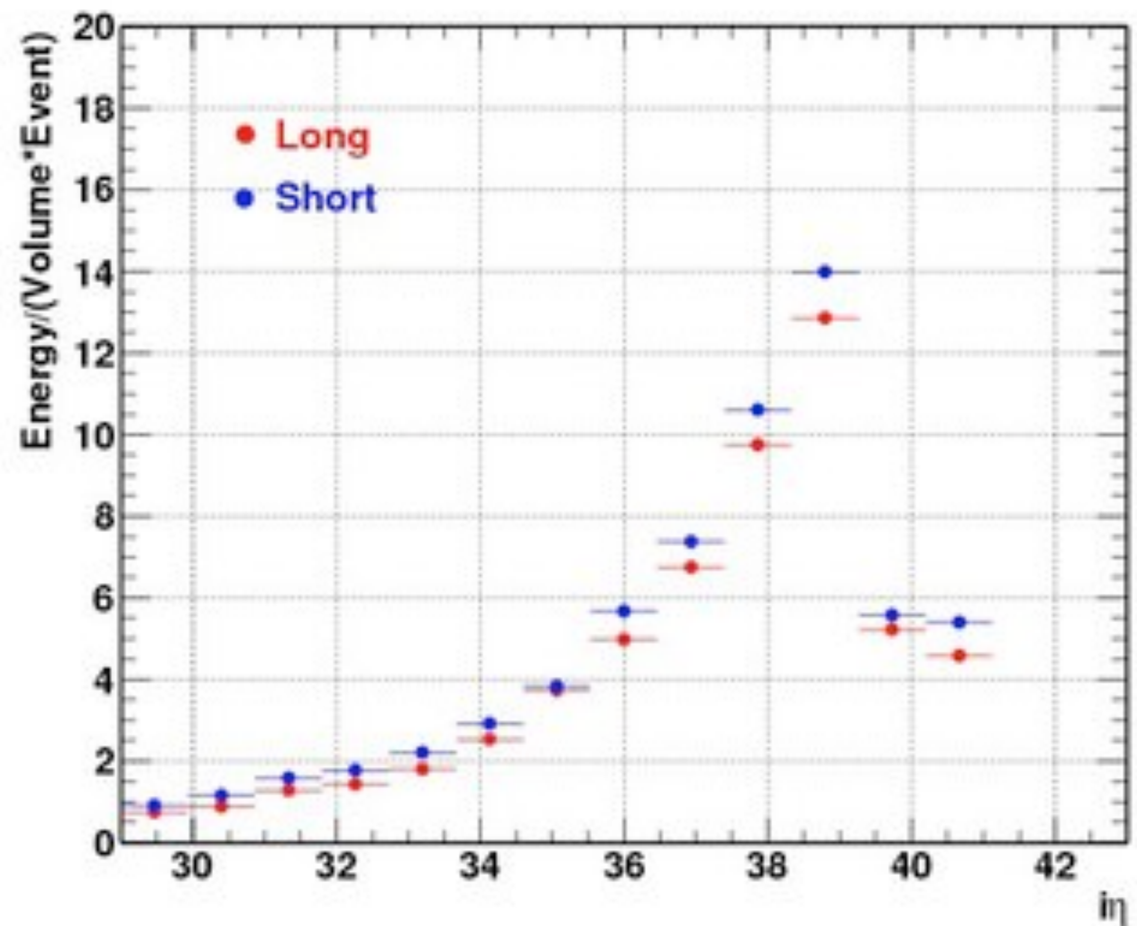
Conclusion

- We have a dijet mass spectrum that extends to 2 TeV GeV with ~2.9 pb^{-1} data.
- The dijet mass data is in good agreement with a full CMS simulation of QCD from PYTHIA.
- There is no evidence for dijet resonances
- We extended excluded mass limit for dijet resonance models beyond Tevatron and ATLAS.
- First CMS research paper based on these result will be submitted to PRL in this week.

Back-up

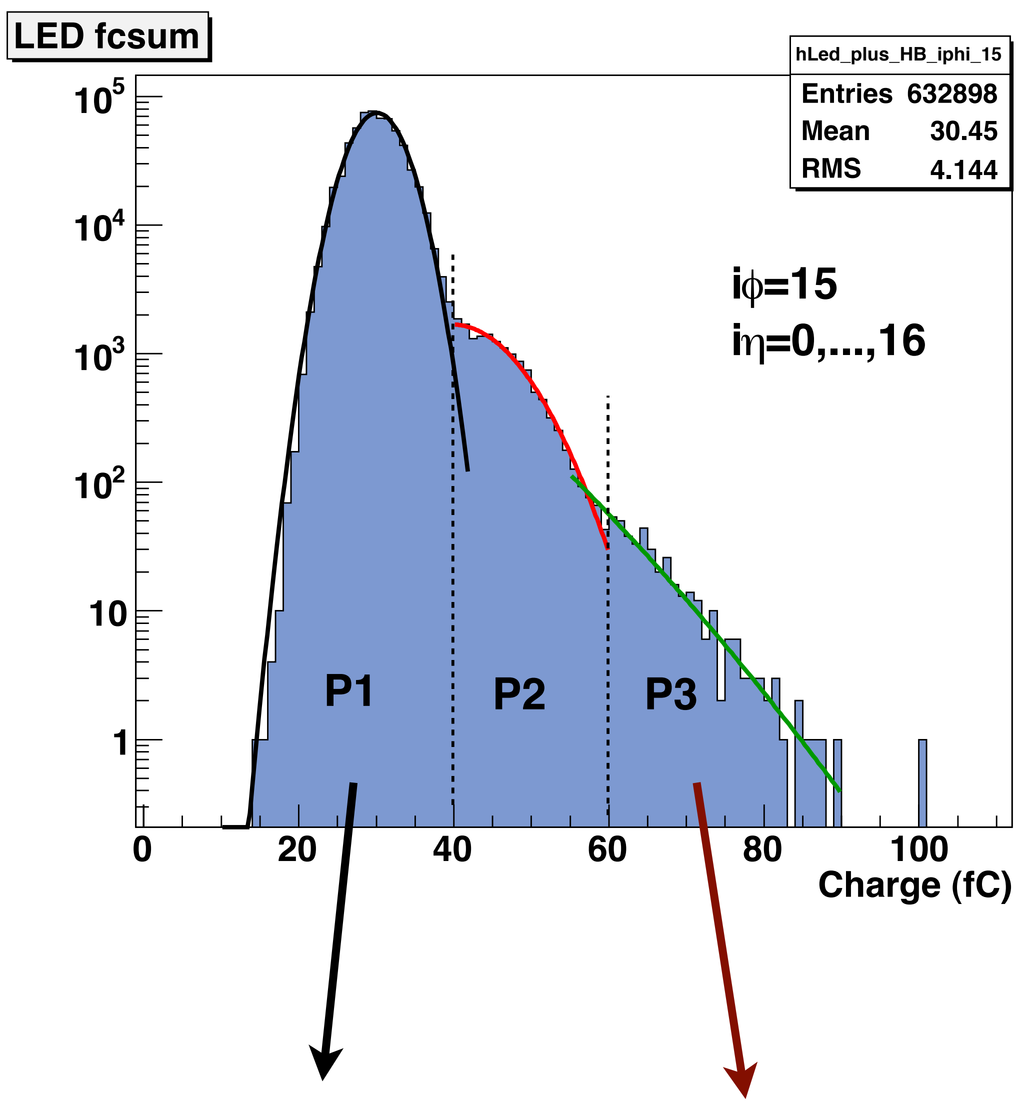
Beam Splash 2009



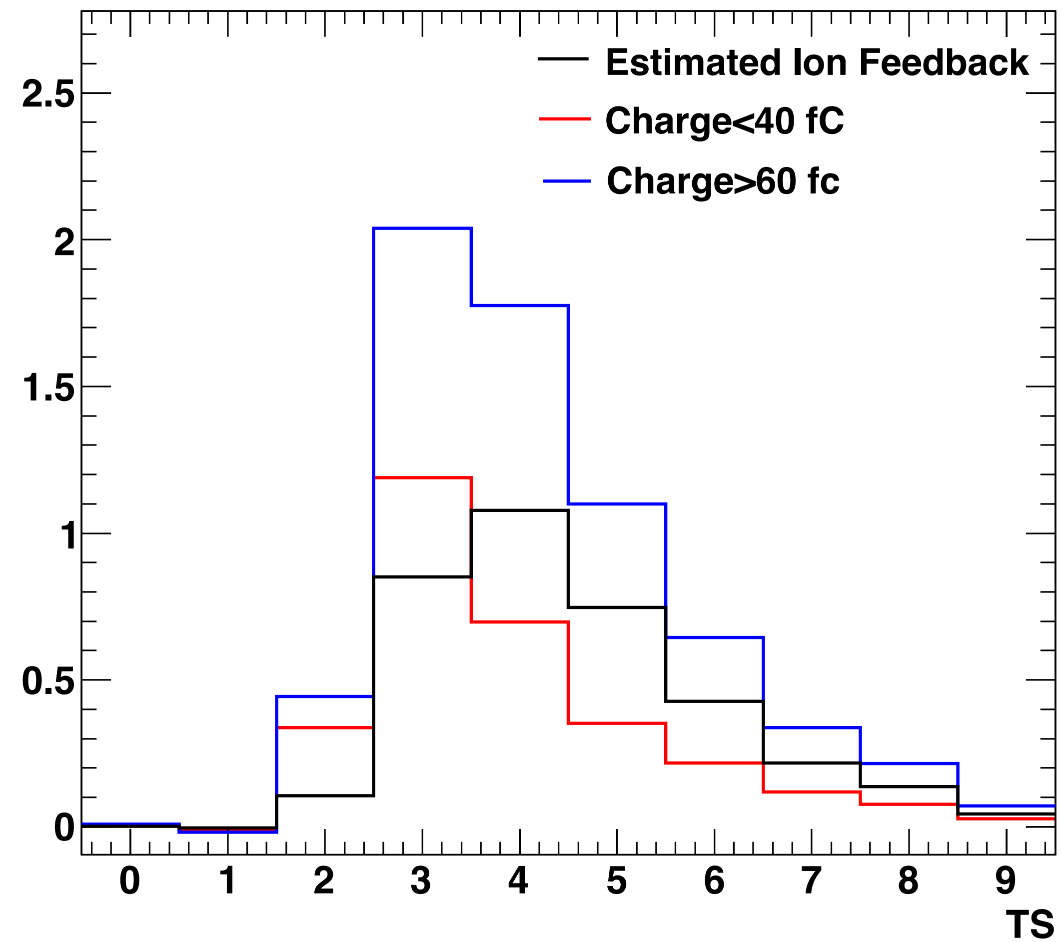


- I spent some effort to determine HF calibration constant in 2009 Beam splash data.

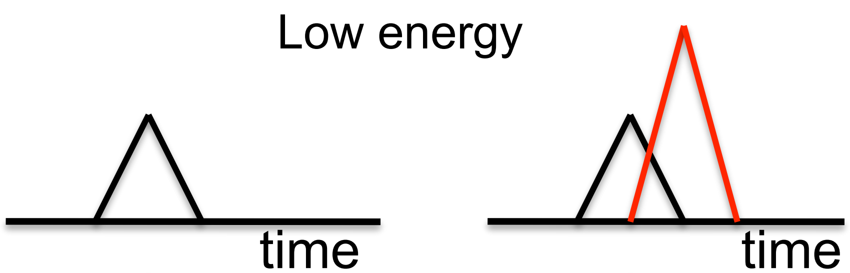
Estimation of IFB Signal



w/o ion feedback   w/ ion feedback



- Ion feedback signal starts 1 TS later.



IFB Signal = Signal in P3 - Signal in P1

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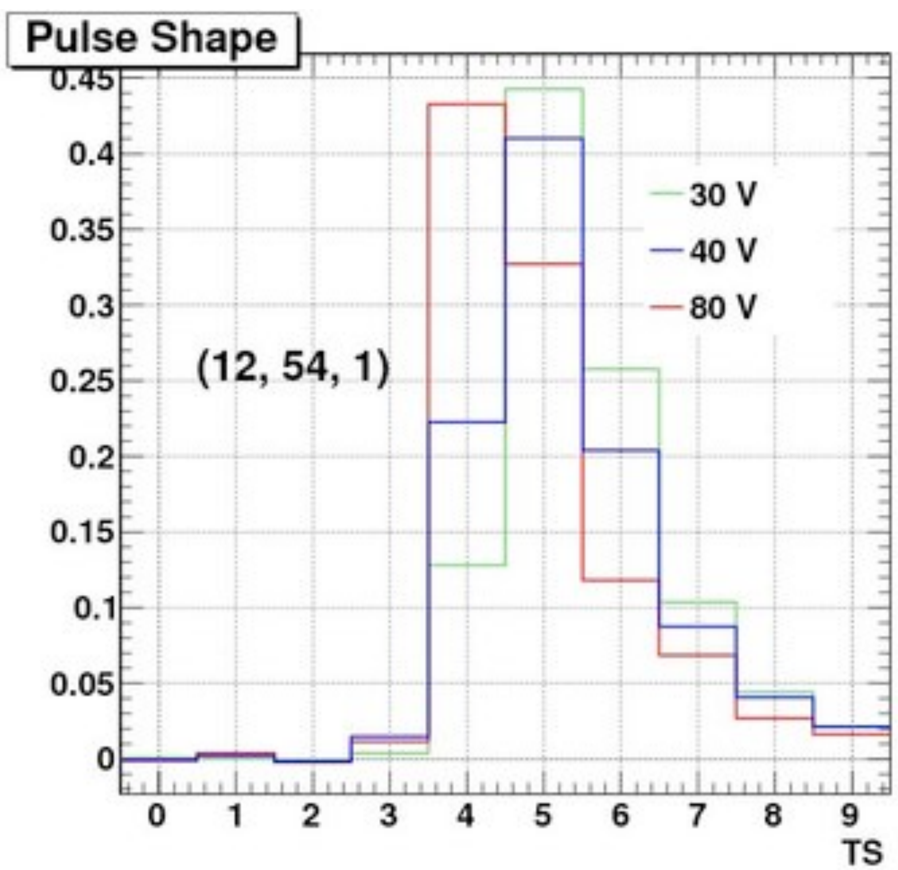
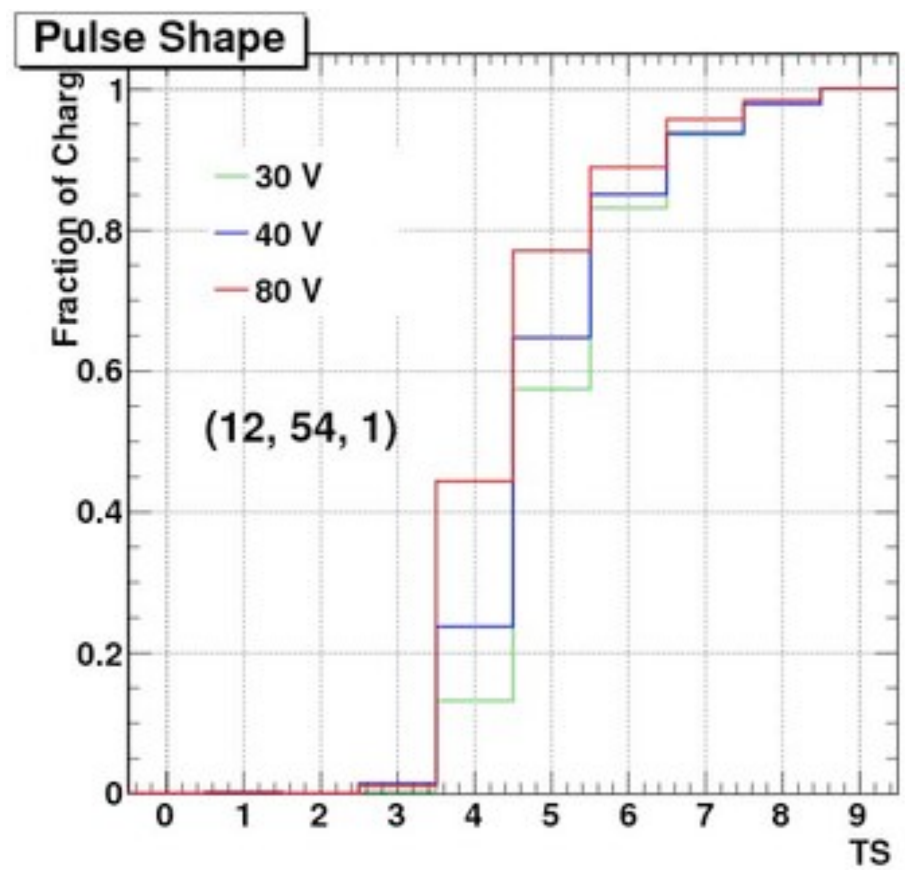
PFG task N.9 - Investigations on HBP14/4 operating at 40V

- Compare Pulse Shape in 80 BV, 40 BV and 30 BV
- HBP14_RM4
  - ✓ iphi:54, depth:1, zside>0 and ieta:1,2,3, ..., 16





☑ HBHE uses 4 TS for reconstruction.

☑ Containment becomes worse as we lower the BV.

Jet Commissioning with First Data

- I looked at JetID cuts criteria in 2009 MinimumBias Collision Data. (CMS AN-2010/030 & PAS JME 10-001)